# RAILWAYS TO-DAY

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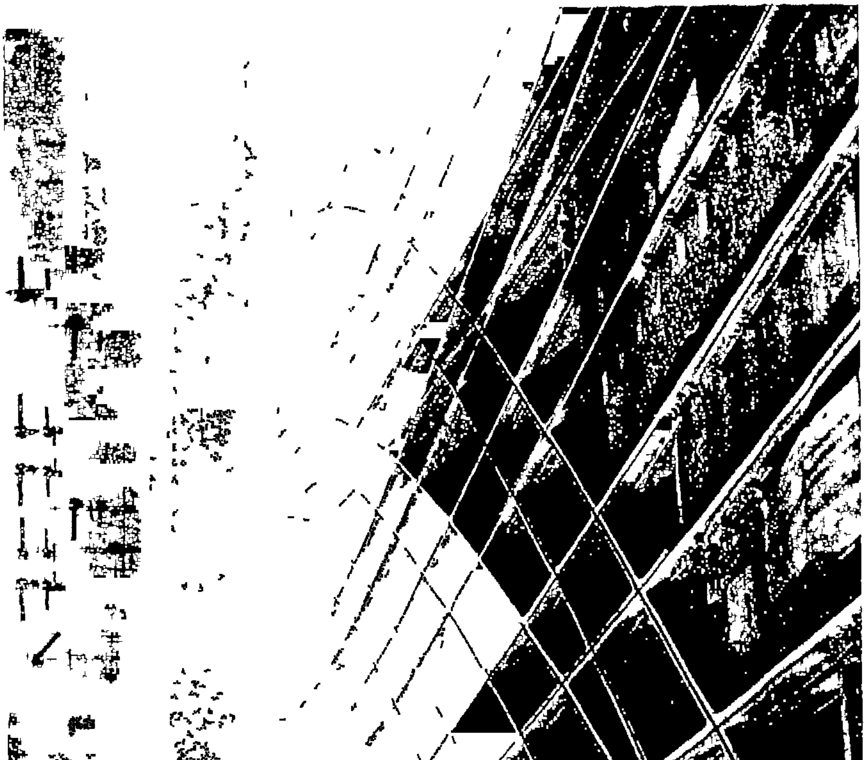
PLATE I



Crossings at entrance to Central Station, Newcastle-upon-Tyne

*Photo Topical*

THE PAGEANT OF PROGRESS
*General Editor* J W BISPHAM, O B.E , M A , B Sc.

# RAILWAYS TO-DAY

BY

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OXFORD UNIVERSITY PRESS
LONDON NEW YORK TORONTO

PRINTED 1938 IN GREAT BRITAIN AT THE
UNIVERSITY PRESS, OXFORD, BY JOHN JOHNSON

*To*

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THE author and publisher wish to make grateful acknowledgement of the courtesy of the London Midland & Scottish, the London & North Eastern, the Great Western, and the Southern Railway Companies, and the *Railway Gazette* in supplying photographs of many of the above illustrations

## CHAPTER I

# INTRODUCTORY AND HISTORICAL

We are so accustomed in these days to take railways as a matter of course, like the hills, that it may be a surprise to some of us to be reminded that, until a little over a century ago, railways were not in existence as public carriers. At the beginning of the nineteenth century passenger travel over a long distance was still effected by means of the stage-coach.

Since that time probably more than three-quarters of a million miles of railway have been laid down on the face of the earth and in almost every part of it, and the railway has entered so intimately into the social and industrial life of the community that it has become virtually a vital necessity of that life. It has been often remarked that railways play a part in the national economy comparable to the functions of the circulatory system in the human body. They constitute the arteries and veins through which flow the raw materials and finished products which are the life-blood of industry.

It is to Great Britain that the world owes the idea of railway transportation. About the middle of the sixteenth century the people of this country began to bestir themselves in the matter of roads—then the chief and, indeed, practically the only means of communication within the country. This recognition of the value of roads was a sure sign that the country was awakening from the long slumber of the Middle Ages. Road-making continued during the seventeenth and part of the eighteenth century, but the roads were rough and indifferent, as may be inferred from the fact that in the first part of the eighteenth century the carriage of goods by wagons, for example, between London and Exeter cost as much as £12 per ton. About the middle of the eighteenth century, however, great efforts were made to improve the roads, so that by the year 1825, when

the first public steam railway in England was inaugurated, there was a network of excellent roads in very good condition covering the whole kingdom

To return a little in the order of events, we may notice that, as the result, doubtless, of the gradual improvement of the roads, stage-coaches were introduced about the year 1660, and in 1662 six of these vehicles were running between different points They have been described as 'dirty, clumsy and lumbering machines, more like hogsheads on wheels than anything else' In 1669 a stage-coach ran from Oxford to London in thirteen hours In 1706 stage-coaches ran from York to London in four days, starting on three days in the week In 1712 a coach ran from Edinburgh to London once a fortnight, occupying thirteen days on the journey and requiring the employment of eighty horses

In 1784 the first mail-coach was put on the road between London and Bristol Previous to that date His Majesty's mails were carried by mail-carts or by the post-boys riding on horseback—not always too safely The new mail-coaches found great favour with the public and rapidly multiplied in number, so that within two years from the installation of the Bristol coach no fewer than twenty coaches were running out of London every night in different directions, and within fifty years, that is to say, by the year 1834, there had been developed a complete system of road travelling by night mail-coaches and by fast day coaches running in competition with them

The vehicles were continually improved, keeping pace with the improvement of the roads, and they attained an average speed of eight to ten miles an hour and even, in some cases, twelve miles Travelling by them, however, was a very expensive business and not within the reach of the poorer classes For example, a passenger travelling from London to Edinburgh in 1830 paid £10 if he travelled outside or £14 inside, and the journey occupied forty hours To-day the single first-class rail-

way fare for the same journey is £4 6*s* 8*d* and the third-class £2 12*s*

The coaches continued to run up to the year 1840 and in some parts of the country even some years later It was only gradually that they were elbowed out of existence by their rapidly growing rivals, the railways At the beginning of the nineteenth century the only means of transit between the smaller towns and villages was by means of post-chaises or private carriages for the wealthy, and for the less well-to-do the humble carrier's cart, such as Mr Barkis drove, or the slow and ponderous stage-wagon Travelling was even then so expensive a luxury that a journey was undertaken only under the most pressing necessity, and many of the roads were so ill-constructed that in bad weather they were almost impassable

The first conception of a permanent way specially adapted for wheeled vehicles has been put by one railway historian as far back as the time of the Babylonian empire Into these early origins we cannot enter It must suffice to note that about the beginning of the seventeenth century somebody, now unknown, hit upon the plan of laying down parallel baulks of timber to form tracks or tram-roads for the easier haulage of heavy loads in wagons drawn by horses In the eighteenth century similar tracks, consisting of oak rails laid upon blocks of wood, were in common use for the conveyance of coal from the mines of Northumberland and Durham to the River Tyne In this case the vehicles that ran over these 'wooden ways' had flanged wheels At a later period, in order to prolong the working life of these timber tracks, iron plates were laid over the upper surfaces of the timbers The term 'platelayer', which is still used to describe a man engaged on work on the permanent way, is derived from this early practice of laying iron plates on timbers

The next step to be noticed is the use in 1776 at the Sheffield colliery of cast-iron rails Of right-angled

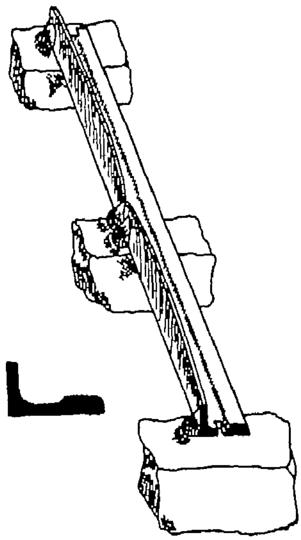


FIG 1 Tram-line section on stone supports (1805)

section, they were laid upon wooden sleepers and required no flanges to the wheels of the vehicles In 1789 a railroad or tramway was constructed at Loughborough having cast-iron rails resting on stone blocks instead of wooden sleepers These rails required the vehicles that were to run over them to have flanged wheels As far as the general design goes, the essential features of our modern permanent way—the ballast, sleepers, chairs, and rails—had been settled before the end of the eighteenth century

Thus in the evolution of railways there was first the conception of the 'rail way' itself—that is, the wooden or iron track which, as a substitute for the rough roads

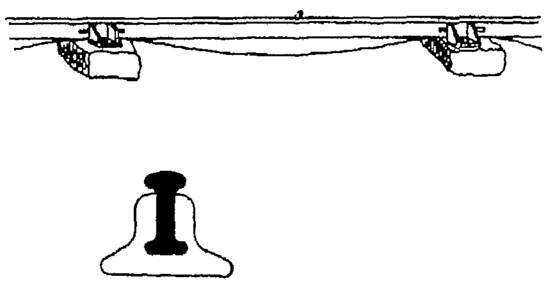
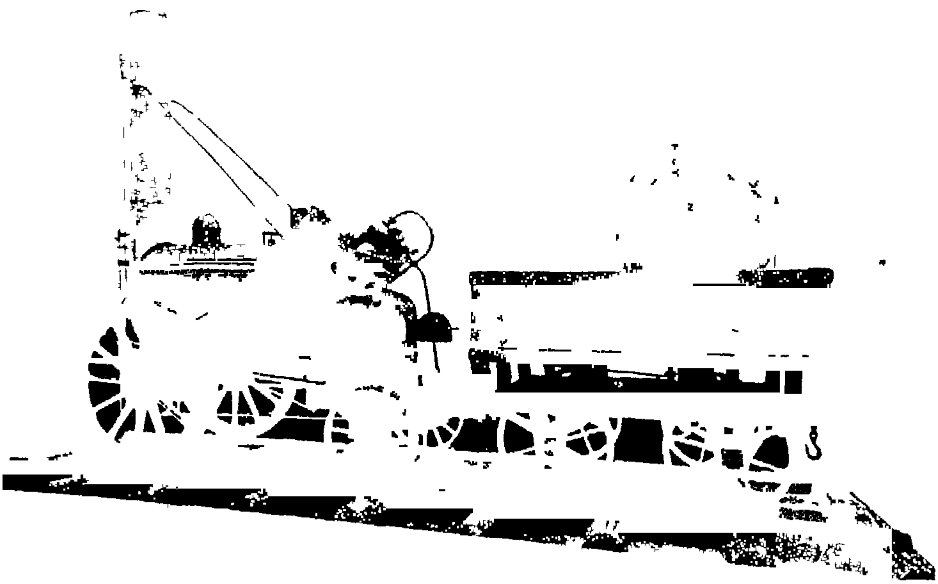
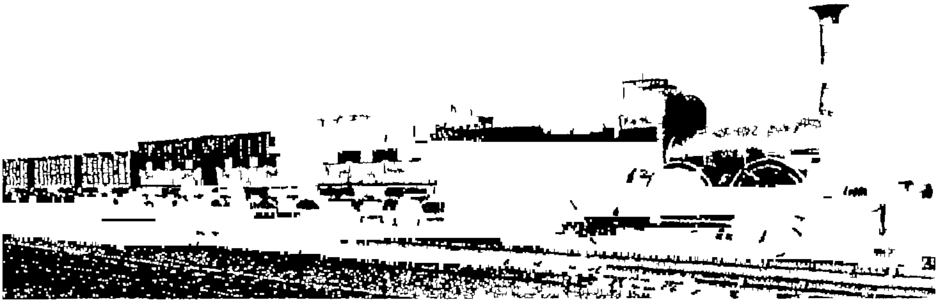


FIG 2 George Stephenson's fish-belly rail, Manchester–Liverpool Railway (1823)

of the period, enabled horses to pull far heavier loads than before, because of the great reduction thereby effected in the frictional forces At a later date there came the birth of the steam locomotive, which was





(1) George Stephenson s Rocket'—a replica of the original engine, in the Science Museum London
(2) Train on the Liverpool and Manchester Railway
(3) The 'Cornwall', a single-driver locomotive on the former London and North Western Railway, 1847, as rebuilt *By courtesy L M S R*

PLATE 3

The three levels of the St. Gotthard line at Wasen, linked by spiral tunnels

The rack railway up Mount Pilatus before electrification  The photograph shows the entrance to the Esel tunnel just below the summit

*By courtesy of the Railway Gazette*

destined to provide the railways with a new and mighty motive power It was first designed as a 'steam carriage' to run on ordinary roads It was not until some forty years afterwards that the steam locomotive was adapted to travel on the railways, which were already in existence, and thus to displace the horse as the tractive power

Of the early history of steam locomotion (including both road and rail) we can deal only with a few salient

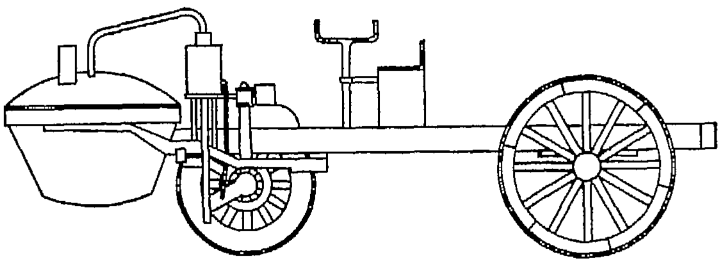


FIG 3 Cugnot's steam engine

features Nicholas Joseph Cugnot, a French mechanic, was probably the first, in 1769, to invent and build a steam locomotive Compared with a modern steam locomotive, either of the road or railway type, Cugnot's steam carriage looks rather like a Heath Robinson conception It did not attain a speed of more than about 3 miles an hour, but it marked a definite beginning William Murdoch, a Scotsman, in or about 1786, made models of steam road carriages, one of which is to be seen at the Science Museum, South Kensington, the other being preserved at Birmingham Later, in 1797, Trevithick, a Cornish engineer, produced his first model of a steam carriage This is also preserved at South Kensington, so that it is possible to compare it with a copy of Murdoch's model

It should be noted that these earliest steam locomotives were designed for tractive work on the roads In 1804 a railway locomotive was produced by Trevithick and first ran on a tramway in South Wales This remarkable engine was not invented solely for tractive

purposes It was designed to pump water, to work a hammer, to wind coal, and to travel not only on the tramway but also on the road, hauling a load of coal! It has been selected for special notice here because of one striking feature of its design The exhaust steam from the cylinders was turned up the chimney, and thus was

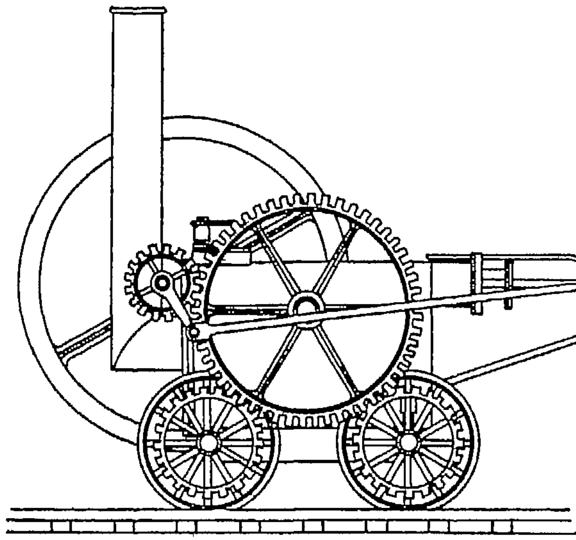


Fig 4 Trevithick's locomotive (1804)

initiated the method of obtaining forced draught for the fire, which is still an essential feature of the modern steam locomotive

We must pass over numerous other engines that were designed by Trevithick and others, and come to George Stephenson, perhaps the most famous of all railway pioneers It should be noticed that Stephenson was not the father of the railway, which, as we have seen, had been in existence for many years before he came into prominence, nor was he the inventor of the locomotive Nevertheless, in the earliest days of our steam-operated railways he played a dominant part in the construction of the great majority of the public railways that formed

the nucleus of our present railway system They were nearly all planned, built, and equipped by him or, at least, with his active help

On 27th September 1825 the first steam public railway in all history—the Stockton and Darlington Railway—was opened for traffic Stephenson had planned and laid the line, he designed every detail of its equipment and built its first locomotive This locomotive, known as 'Locomotion No 1', was only 6½ tons in total weight, including the tender, and on the inaugural run it succeeded in hauling a train of thirty-eight vehicles and attaining a speed of 12 miles an hour

Steam locomotion on the railways was, however, still in the experimental stages For some years yet horse-power competed with Stephenson's 'Locomotion No 1' over the Stockton and Darlington Railway It was not until five years later, in 1830, when the Liverpool and Manchester Railway was opened, that the practicability of railway transport with steam-hauled trains was clearly demonstrated The history of the establishment of this railway deserves some particular notice It was the first railway made with public money and for the public benefit, the first railway to use steam locomotives for both passenger and freight traffic, and it marked the birth of the railway system as we know it to-day

About the year 1820 the relations between Manchester, as the great manufacturing town of the north, and Liverpool, as the nearest shipping port, had created a large traffic between the two places, for the conduct of which the road wagons and canal barges had proved to be totally inadequate In the year 1821, therefore, a committee of merchants of Liverpool was formed to draw up a scheme for the construction of a railway or tramway between Liverpool and Manchester It should be noticed that the question of the motive power to be employed—as between horses, on one hand, and the steam-engine, with which George Stephenson was then experimenting, on the other—was left open

In 1829, shortly before the line opened, the directors offered a prize of £500 for the locomotive which should best fulfil certain conditions that they laid down Against three competing locomotives, Stephenson's *Rocket* succeeded in fulfilling the conditions specified—and, indeed, went considerably further—and won the prize It travelled at what was till then the undreamt-of speed of 35 miles an hour 'Now,' exclaimed one of the directors, 'has George Stephenson at last delivered himself!'

The principle of railway transportation was now established in the face of violent opposition Of course, many vested interests were threatened by the coming of railways, such, for example, as the interests of landowners, of stock-holders of coaching companies, and also canal and turnpike interests The late Sir George Findlay, who was General Manager of the old London and North Western Railway, thus described this opposition 'Every weapon that the prejudice and narrow-mindedness of the many, or the alarmed avarice of the few whose interests were threatened by the impending change, could devise, was brought to bear without scruple, even to the length of personal abuse and calumny levelled against the promoters The most absurd statements were gravely put forward and believed in, the smoke of the engines would kill the birds, cattle would be terrified, and cows would cease to give their milk, the sparks from the engines would set fire to the houses and manufactories on the line of route, the race of horses would become extinct, and many other direful consequences would ensue, amidst which the absolute ruin of the country would shrink to the insignificance of a detail! The first surveys had to be accomplished, in many cases, by stealth, and were, in some cases, resisted to the extent of the employment of armed force '

In the first year of its working the Liverpool and Manchester Railway was a greater success than even its promoters had ventured to predict Although the actual

cost of construction of the railway was three times the estimated cost of £400,000, a dividend of 8 per cent on the larger amount was declared

The great success of the Liverpool and Manchester Railway, as was to be expected, let loose a flood of railway enterprise all over the country Lines were soon projected between all the towns of any importance in the kingdom and even between remote villages This 'railway mania', as it was called, rose to such a pitch that, in the year 1846, no fewer than 1,263 Bills seeking authority to construct railways were presented to Parliament for sanction It may be added that only 120 of these proposals actually became law

The first railway in Ireland was opened in 1834, and it ran from Dublin to Kingstown (now Dun Laoghaire) In 1835 the first German railway (the Ludwigsbahn) was opened from Nuremberg to Furth with Stephenson's locomotive *Der Adler* In the same year the London and Southampton Railway was opened from Nine Elms to Woking and extended to Winchfield later in the year The first portion of the London and Birmingham Railway was inaugurated in 1837, and the first section of the Great Western Railway—from Paddington to Maidenhead—was opened in 1838

In the year 1839 the first railway in the Netherlands was opened from Amsterdam to Haarlem, and the first railway in Italy from Naples to Portici The first railway in France was the St Etienne to Andrézieux railway, which was formally opened with horse traction in 1828 Passenger traffic began in 1832 and steam traction in 1844

Records show that upwards of one thousand separately authorized railway undertakings have existed in Great Britain In the year 1921, as the result of amalgamations, mergers, and bankruptcies, there were less than two hundred During the Great War (1914–18) the control of the whole of the railways of the country was assumed by the government, although the actual

working was vested in a Railway Executive Committee composed of the railway managers

In 1921 the Railways Act was passed through Parliament As its first clause states explicitly, this was a measure 'for the formation of the railways of the country into groups, as a means to the reorganization and more efficient and economical working of the railway system of Great Britain' By the Act no fewer than one hundred and twenty separately constituted railway companies in Great Britain were merged into four distinct and independent railway companies—the 'Big Four', as they are often called They are, naming them in order of size (1) the London, Midland and Scottish, (2) the London and North Eastern, (3) the Great Western, and (4) the Southern, railway companies In what follows we shall frequently refer to them by their well-known initials L M S R , L N E R , G W R , and S R respectively

Besides the 'Big Four' there are many other railways in Great Britain and in Ireland, including electric railways, light railways, joint railways, and miniature railways Reference will be made in subsequent chapters to some of these railways in connexion with special subjects Of the world's railways, spread over the five continents, it must be sufficient to repeat here what was said at the outset of this chapter, that their total mileage amounts probably to over three-quarters of a million

Before we come to a detailed examination of the making and working of railways, let us remember that the essential advantage of a railway is twofold (1) To move vehicles on the railway requires an extremely small expenditure of power in relation to their weight, because the frictional resistance offered to forward motion by a hard, smooth-tyred wheel rolling on a hard, smooth surface is very much less than that of a wheel—even a pneumatic-tyred wheel—rolling on a relatively rough surface, such as a road (2) The direction of the movement is completely controlled, the vehicles

cannot deviate from the line of the rails and, therefore, no steering is necessary

These two advantages are great and decisive, so that there seems little likelihood of railways losing their importance As time goes on better and still better methods of moving and controlling trains will be evolved, but there is every probability that railways—ways of rails—will continue to be useful for centuries

In the following chapters the aim throughout has been to keep in mind that a railway is a whole, like a watch or a wireless set, and that it 'works' or 'goes' only because its different parts are properly fitted in to the whole and their functions exactly co-ordinated If this book gives a fairly clear exposition of how and why a railway works, it succeeds in its purpose, however much may have been omitted If it does not, it fails, however much may have been included

## CHAPTER II

# THE ROUTE

LET us now suppose that it has been decided to build a railway, and let us consider the problems that arise in the choice and planning of the route that it is to follow In this choice many considerations must be taken into account and weighed carefully one against the other

Obviously, one would say that the ideal route should be perfectly straight and perfectly level, but it is rarely, if ever, possible for this ideal to be realized in practice Deviations from the straight may be required in order to tap additional sources of traffic on the way Again, the gradients of the line must be as few and as gentle as is practicable, because the cost of working the line is increased as the gradients are increased in number or steepened This, of course, frequently necessitates deviations of the route from the straight

It is true that, by making deep cuttings, high embankments, lofty viaducts and long tunnels, a fairly level line may be laid through hilly country, but the costs of construction of the route will be very greatly increased thereby Unless, therefore, a great volume of traffic is likely to be attracted to such a route, it may not be possible, from the revenue obtained by the operation of the line, to pay interest on the greatly increased capital expenditure involved in its construction Generally speaking, in hilly country a line which follows the course of a river valley has to encounter less engineering difficulty than has a line which cuts across the more or less parallel valleys of a watershed

In planning a railway route, therefore, the main factors to be taken into account are the cost of constructing the line, the cost of operating it, and the probable volume of traffic which will be carried over the line when it is opened and working

The constructional cost is determined chiefly by the

physical character of the country that is to be traversed The most expensive construction is usually entailed when reasonably gentle gradients are carried through mountainous country, though it should be noticed that, if the cost of the land to be acquired is included, railway building through towns and cities may also be very expensive Of course, increased constructional cost may be justified if there be a fair prospect of the completed line carrying a big volume of traffic, and so earning enough revenue to pay interest on the capital expenditure involved

The cost of operating a line depends largely on the number and the steepness of the gradients along the route It is also influenced by the weight of the trains, the frequency of stops, the volume of traffic, the suitability of the water-supplies, and the nearness of coal If the line is to be run at a profit, the volume of traffic must be sufficient to cover both the operating cost and the interest on the capital In the case of a route where the volume of traffic is expected to be small, therefore, the railway engineer must pay very close attention to the constructional cost, so as to keep down the capital expenditure

This question of gradients is one of very great importance to any railway As the gradients become steeper, not only do they set lower limits for the loads which can be hauled by a given locomotive, but also they reduce the average speeds permissible over the line Of these two limitations, the limitation of train-loads is the more important, because limited loads mean that more locomotives have to be used and more train-crews, so that the cost of working, particularly the working of freight trains, is affected directly by the steepness of the gradients The steeper the gradients, the greater the working costs

The degree of steepness of a gradient, as the reader probably knows, is expressed by stating the ratio between the rise in height and the horizontal distance

traversed For example, when we speak of a gradient of 1 in 600 we mean that, for every 600 feet of forward distance, measured horizontally, the line rises or falls vertically 1 foot If we consider main lines, on which there are fast and frequent passenger trains and heavy freight traffic, gradients of 1 in 300 and flatter are usually regarded as easy, 1 in 200 is a reasonable limit of steepness, especially if it is over a long, unbroken stretch of route, and 1 in 100 is decidedly steep

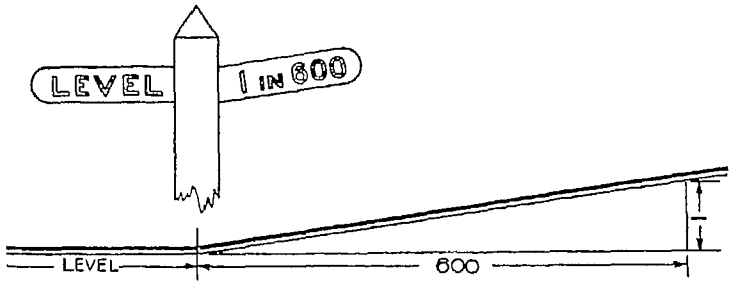



FIG 5

With these standards in mind let us look, for example, at the west coast main line of the L M S R For the first 150 miles of its length it has no gradient steeper than 1 in 328, except for the first $1\frac{1}{4}$ miles, where there is a steep ascent, at 1 in 70 to 1 in 105, from the terminus at Euston to Camden This section of the line was a part of the original London and Birmingham Railway route, and when it was opened an engine-house was installed at Camden and, by means of ropes, the trains were hauled up the incline

Although such assistance of a winding-engine has long been abandoned, it is customary nowadays to provide many of the heavier trains with the help of a banking-engine in the rear from Euston to Camden, in order to avoid loss of time and even the possible 'stalling' of the train on this incline Similar banking assistance is given to heavy trains on many other routes—for example, trains leaving the Victoria terminal station of

the Southern Railway At Victoria the help is necessary, owing to the 1 in 61 gradient which leads from the ends of the platforms to Grosvenor Bridge over the River Thames

The influence of gradients on the operating cost is well illustrated in the case of the L M S R main line to Scotland—the west coast route If we except one or two sharp ascents near Warrington, Wigan, Preston, and Lancaster, this route does not become really severe until Carnforth is reached From Carnforth the line rises for 31 miles to an altitude of 915 feet above sea-level at Shap Summit, and then falls in like distance practically to sea-level at Carlisle On passing into Scotland over what was the old Caledonian main line, the railway climbs, in a distance of 50 miles, to an altitude of 1,015 feet at Beattock Summit, and then falls again, in just over the same distance, to a level but little above that of the sea at Edinburgh and Glasgow

The steepest part of the Shap ascent is just below the summit, where for 4½ miles there is a gradient of 1 in 75, followed by 7 miles of descent down a gradient of 1 in 125 from Shap Station to Clifton Beattock Bank is much more severe, however, for 10 continuous miles the gradient is between 1 in 69 and 1 in 88

It is because of these two stiff climbs—Shap and Beattock—that certain express trains, which make the earlier part of the journey from London with one engine only, may have to be 'double-headed' (i e be hauled by two engines) over these steep stretches Alternatively, the trains which run combined between Euston and Crewe may have to run divided north of Crewe or of Preston

For the climb up Beattock Bank a number of 'banking' engines (i e engines whose duty it is to push the train from behind) are kept constantly in steam at Beattock Station Except those trains which are double-headed from Carlisle, or passenger expresses hauled by powerful engines of recent design (such as the *Royal*

*Scot* or the *Princess Royal* type), every train going north has to stop at Beattock in order to obtain rear-end assistance up to the summit.

Similar banking assistance is available also at Oxenholme, Tebay, and Carlisle for the Shap climbs in both directions, although, owing to the less severe gradients of Shap, this help is needed, as a rule, only by freight trains.

It may be noticed here that the highest British railway summit is 3,540 feet above sea-level, on the Snowdon mountain railway, though this is a rack railway; the next highest summit is between Leadhills and Wanlock Head, 1,498 feet, on the Caledonian section of the L.M.S.R. The steepest gradient in the world on an adhesion railway (i.e. a railway in which the wheels grip the rails by simple friction) is 1 in 11 on a section of the Guatemalan State Electric Railway, which began working on 30th March 1930. This line climbs from 2,300 feet to 7,650 feet, and the entire route lies through a broken and mountainous territory.

Just as the strength of a chain is no more than that of the weakest link, so the steepest gradient of any section of route is the 'ruling' gradient for that section. It rules or determines what are the maximum train-loads to be allowed. For example, let us look at the G.W.R. main line to Cornwall. West of Newton Abbot the line is carried on the southern slopes of Dartmoor, close to the sea-coast, and the gradients needed to cross the several river valleys encountered are exceedingly steep. For 2 miles up to Dainton Summit the line steepens from 1 in 57 to 1 in 47, with one short length as steep as 1 in 36. The first mile of the following descent to the valley of the Dart at Totnes is only a little flatter than 1 in 40. Then follows a formidable climb to Brent, beginning with a couple of miles at 1 in 51, succeeded by 1½ miles at 1 in 90 and half a mile at 1 in 125. After crossing a table-land, the line drops from Hemerdon signal-box to Plympton for 2¼ miles at an average inclination of 1 in 42.

One consequence of these steep gradients is that even the new 'King' class of locomotives, which are rated as capable of hauling 525-ton express trains from Paddington to Newton Abbot, are not permitted to haul between Newton Abbot and Plymouth more than ten 70-foot coaches, the total weight of which, with passengers and luggage, is about 380 tons Of course engines of less power than the 'King' class are more severely limited in the loads they are permitted to haul

Great Britain is a long, straggling country, with the capital, London, almost tucked away in the south-east corner of it, and there are many thickly populated industrial districts scattered very irregularly about the country Such a state of affairs obviously does not make it easy to plan a really neat system of railways, with clean-cut geographical edges and no ragged ends Great Britain is, indeed, quite different from France in this respect

France may be regarded as being roughly—very roughly—circular in form, and Paris is not very far from the centre of the country This makes possible a most convenient arrangement of main lines radiating evenly, rather like the spokes of a wheel, from the capital in all directions Another advantage is that the three great commercial cities, Lille, Lyons, and Bordeaux, are so situated that the main lines to them from Paris fit in with the general scheme of radiating main lines

Again, France is preponderantly agricultural, so that, outside a few great industrial and commercial areas, the population is fairly evenly distributed When it is remembered that, in addition to these advantages, the French railways were, from the beginning, planned as one connected whole, it will be readily understood that they are much better arranged than those of any other big and populous country

In the United States the absence of centralized regulation at the outset and the consequent absence of any

initial planning of the railways as a whole has resulted in the creation in the thickly populated parts of the country of a railway system as complicated as that of Great Britain

In Great Britain and in other countries problems have arisen in the working of some of the earlier constructed railways owing to the difficulties of the routes that were originally chosen These difficulties have sometimes become so acute that the engineers have been driven to make considerable alterations of the original routes In many cases roundabout routes have had to be cut off One example from America may be cited

The Southern Pacific Railway constructed a 'cut-off' line across the Great Salt Lake of Utah The original main line from Omaha to San Francisco went round the north side of the lake, the line going over heavy gradients, in places as steep as 1 in 60 for considerable distances, the trains having to climb in all 1,515 feet The new line across the 31½ miles' width of the lake not only reduced the distance from 147½ to 103 miles, but also substituted a perfectly straight and level route for the previous ascents It may be noticed here that the St Gotthard Railway of Switzerland is carried similarly across the Lake of Lugano on a causeway which was tipped on to an under-water glacial moraine near Melide

Among all the countries of the world Switzerland is that in which the terrain has created the greatest difficulties for the railway constructor It is, in consequence, the country where some of the most wonderful feats in railway engineering have been achieved Because of its central position in Europe, several of the most important trans-European railway routes pass through Switzerland and must, therefore, traverse the mountain passes of the Alps This has necessitated the construction of many long tunnels to carry these lines from the valleys on one side of the Alpine watershed to those on the other

The Simplon Tunnel, 12¼ miles in length, is the longest railway tunnel in the world (apart from the London Tube tunnels, of which the longest continuous tube is the line from Golders Green to Morden via the Bank, which is 16 miles 1,100 yards long) The St Gotthard Tunnel, 9¼ miles long, and the Lotschberg Tunnel, 9 miles, are two other remarkable examples within Swiss territory

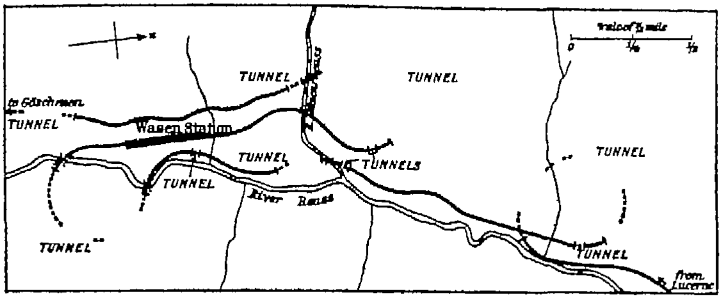



FIG 6 Map of spiral and loops on the St Gotthard route, Swiss Federal Railways

An amazing example of railway planning is seen on the St Gotthard route In ascending the valley of the River Reuss, from Fluelen, on the Lake of Lucerne, to Goschenen, at the mouth of the St Gotthard Tunnel, the railway is carried at one stage of the route through the Pfaffensprung Tunnel, which forms a complete spiral turn, 1,635 yards long Immediately afterwards, opposite the village of Wasen, the railway makes an immense double loop, whereby the level of the line is raised by 400 feet without any increase in the average gradient of 1 in 38½ to 1 in 40 This gradient is maintained for some 18 continuous miles, in the course of which the track rises a total of 2,100 feet (Plate 3)

It may be added that in the 140 miles of the St Gotthard line between Lucerne in Switzerland and Chiasso in Italy there are no fewer than 80 tunnels, all bored through solid rock and aggregating in length 28½ miles,

with 324 bridges of over 32 feet span The total cost of the line was 18½ million pounds sterling, and it was opened on 1st July 1882

On the electrically operated Bernina Railway, connecting the Rhaetian system with the Italian line from Lake Como, the maximum steepness of the gradient is as much as 1 in 14, which continues over long stretches of route The steepest adhesion line worked with steam locomotives is probably that between Halberstadt and Blankenburg, in the Harz Mountains of Germany, which has a long continuous stretch of line inclined at 1 in 16½

Ascents steeper than these can be climbed only by the help of the 'rack' or, as it is often called, the 'rack-and-pinion' In the rack-and-pinion method of propulsion, in place of the ordinary locomotive driving-wheels there is a toothed pinion-wheel, the teeth of which engage in the teeth of a steel rack, which is strongly secured, usually in the centre of the track, between the two running rails This method limits severely the speed of trains, but on exceptionally steep ascents the use of the rack is indispensable It enables gradients to be increased to a maximum of about 1 in 2, which is the ruling gradient, for example, on the mountain railway from Alpnachstad, on the Lake of Lucerne, to the summit of Pilatus (Plate 3)

There are many similar mountain railways in Switzerland, and it is the legitimately proud boast of the Swiss that no fatal accident has ever occurred to a passenger travelling by any one of them—so complete are the safety precautions laid down by the Swiss government for their working.

In Great Britain the physical configuration of the land has presented few serious difficulties to the railway engineer. But dense traffic and high speeds had to be provided for, and the British railway engineer's main problem, therefore, has been to lay routes which shall involve a minimum of trouble in their operation and a

minimum of expense in their maintenance British construction costs were greater than American In Britain the land acquired by the railways had to be fenced off, bridges built over many roads and canals, and station accommodation provided in towns where land had a high value All these elements added to the cost of construction and sometimes cramped the plans of the railway promoters, which caused further expense later on when the development of traffic necessitated the widening of tracks and the enlargement of station accommodation

CHAPTER III

# RAILWAY GAUGES

It is clear that, in the development of railways, consideration must have been given at a very early stage to the fixing of definite standards for the dimensions of various parts of the railway system In particular, the question of the distance apart at which the rails were to be laid was obviously a most important one This inner distance between the rails of the track is often called simply 'the gauge' or the 'standard gauge', and it came to be fixed finally for British railways at the curious figure of 4 feet 8½ inches

There has been a good deal of discussion by railway historians as to how this particular width came to be chosen One suggestion is that it was a copy of the distance between the centres of the parallel lines of stone blocks that were used by the Romans in making their roads According to this theory, George Stephenson, who was a Northumbrian, was influenced by the gauge of Roman wheel ruts observed along Hadrian's Wall, which ran from the mouth of the Tyne to the Solway Firth Another suggestion is that Stephenson measured the distance between the wheels of his farm cart and took that distance as a convenient length between the wheels of his early locomotives

Anyhow, whatever the railway historians may eventually decide about the origin of the standard gauge, the facts to be borne in mind are that it was finally fixed at 4 feet 8½ inches, and that, the standard having once been settled, it became difficult and undesirable to alter it Obviously, when a stage was reached at which large numbers of locomotives, carriages, and wagons were running on the 4 feet 8½ inch gauge, any alteration of the gauge would have necessitated not only the moving of the existing rails but also extensive alterations to the rolling-stock, to platforms, and to other line-side structures

*Above* An old broad gauge train on the G W R The third rail enabled the line to be used for either broad or narrow gauge traffic *By courtesy of the G W R*

*Below* Train on the Ravenglass and Eskdale Railway Cumberland This line has a 15 inch gauge *Photo 'Topical'*

Harwich–Zeebrugge train ferry leaving Harwich

By courtesy of L.N E R

As Great Britain was the pioneer in the matter of railway construction, and since many of the earliest locomotives in other countries were of British manufacture, the gauge of 4 feet 8½ inches naturally spread and became standardized in many parts of the world, including the whole of the continent of North America. In Europe also the railway gauge has become standardized at 1·45 metres, which is equivalent to 4 feet 9 inches. This is sufficiently near to the British gauge to make possible the through running of vehicles (via, for example, the Harwich–Zeebrugge and the Dover–Dunkerque train ferries) from English towns to destinations in almost any country on the Continent and vice versa.

Let us notice, however, that Spain and Portugal have a gauge of 5 feet 5¾ inches, and Russia one of 5 feet. It is therefore impossible to run through trains between these countries and the rest of Europe, and passengers have to change trains at the various frontier stations, and all the freight has to be trans-shipped from the wagons of one gauge to those of the other. Oddly enough, the standard gauge in Ireland differs also from the British and from the general European standard, the Irish main lines having been laid on a standard gauge of 5 feet 3 inches. The L.M.S.R. has a detached portion of its system in the north of Ireland and, because of this difference in gauge, the company has to build special rolling-stock for the working of this section of its system. In India a gauge as wide as 5 feet 6 inches is used on the main lines, which, of course, permits the use of locomotives and of rolling-stock of great size.

There was a time when England was threatened with a confusion of gauges. Brunel, the famous engineer of the G.W.R., decided to employ a gauge of 7 feet instead of the gauge of 4 feet 8½ inches, which had already become standardized in other parts of the country. A great 'Battle of the Gauges' followed between the champions of the broad gauge and those of the narrow.

One consequence of the adoption by the G W R of the broad gauge was that the company was able to build locomotives considerably more powerful and speedier than those then running on other lines Not only so, but the carrying capacity of the G W R coaches, because of the extra width to which they could be built, was greater in proportion to their weight than that of other companies' carriages Moreover, the running of the

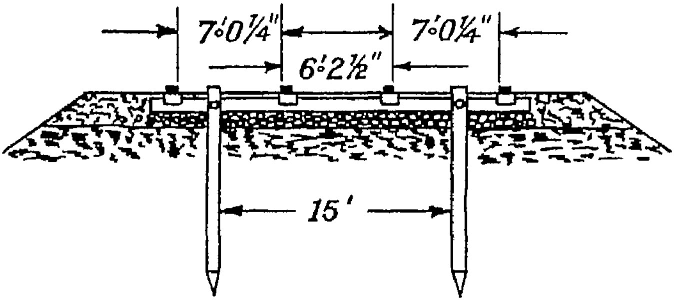



FIG 7 Brunel's broad gauge track
The two uprights shown in this diagram were piles, ten inches in diameter, fifteen feet apart, secured to the sleepers and driven into the ballast

trains over the broad gauge was markedly smoother than it was then on the narrow gauge—as any elderly railway passenger from the west country will affirm!

It should be noticed that, if the pleas of the advocates of the broad gauge had prevailed, the design and the construction of rolling-stock, including locomotives, carriages, and wagons, would have been altered It would have been possible to mount boilers of much larger diameters on the frames of the locomotives and to increase the carrying capacity of the coaches and wagons in proportion to their length, in this way reducing their working costs On the other hand, for the broad gauge the radius of the sharper curves of the track would necessarily be increased, and this would have increased correspondingly the costs of constructing the line.

Brunel does not seem to have realized that the G W R could not be kept apart from, and operated independently of, every other British line With the broad gauge it was impossible to run a G W R wagon or coach on any other railway system in Britain and so 'through running' was barred The adoption of the 4-foot 8½-inch gauge had spread so far in all parts of the world that to widen the narrow to the broad gauge was out of the question The cost of doing it would have been prohibitive Thus it was inevitable that ultimately Brunel's broad gauge of 7 feet should be contracted to the standard figure of 4 feet 8½ inches, and the G W R come into line with the other railways of the country Mahomet had to come to the mountain

To contract the gauge of an existing line is a much cheaper undertaking than to widen it Generally speaking, all that is needed is to shift one rail of each track and make the necessary alterations to the rolling-stock The various permanent structures that are erected along the line—bridges, tunnels, station platforms, signal boxes, and so on—are not greatly affected by narrowing the gauge, though, obviously, they might be very much in the way if the gauge had to be made broader

The story of the change-over from the broad gauge to the narrow gauge on the G W R is one of the romantic stories of railway history The conversion took in all twenty years, from 1872 to 1892 Many years before the actual change was made it had become necessary to lay a 'mixed gauge' along various sections of the G W R main lines This was done by laying a third running rail to each track, thus making it possible to run either 4-foot 8½-inch or 7-foot gauge vehicles.

The last stage of the conversion was to remove the broad gauge altogether In the case of the main lines, this conversion involved some of the most remarkable achievements of railway organization that this country has ever known In 1872 on the Gloucester and Milford Haven section of the system, which, with branches,

totalled 500 miles of track, 5,000 men set to work on the main line and converted the down line in a single week and the up line in the week following

After various important branches had been converted, the 170 miles section from Exeter to Plymouth was tackled, and the gauge was actually changed in two days —21st and 22nd May 1892 Before these dates all the broad-gauge engines and coaches had been taken and worked east of Exeter On 20th May 1892 the 'Cornishman' left Paddington at 10 15 a m on its last journey as a broad-gauge express

What Brunel's initial choice of the broad gauge cost the G W R is difficult to calculate, but it may be noted that, when the decision to change the gauge was first made in 1869, there were 1,500 miles of broad-gauge track in existence, all of which had to be converted, and there were also 700 broad-gauge engines, together with a corresponding quantity of rolling-stock, both passenger and freight, a great deal of which would be of no use for running on the narrow gauge

George Stephenson showed better judgement and foresight When he was planning railways in counties as far apart as Durham, Lancashire, Leicestershire, and Kent, he is reported to have said 'I tell you they must all be 4 feet 8½ inches Make them of the same width, though they may be a long way apart now, depend upon it they will be joined together some day' To-day 'through wagons' are run from Bournemouth in the south of England to Wick and Thurso in the north of Scotland

If we look at a table of the railway gauges in general use throughout the world we shall note that the railways fall into three principal groups, namely, main lines of 4-foot 8½-inch gauge and upwards, intermediate lines of 3 feet 6 inches and of metre gauges, and very narrow gauge lines of 2 feet or thereabouts With regard to Great Britain, statistics show that the length of standard-gauge line open for traffic at the end of 1936 was over 20,000

miles In addition, there were over 100 miles of lines with gauges varying from 1 foot 3 inches to 2 feet 6 inches

Why is it that certain railways are laid down to a gauge narrower than the normal? The primary object is to cheapen the cost of the line By constructing a narrow-gauge railway less land is required than is needed by the standard gauge, a lighter track may be laid, bridges and other structures are less costly to build, and, similarly, the size and power of locomotives and the capacity of coaches and wagons are less, ensuring a proportionate reduction in costs Perhaps the most important advantage is that the use of a narrow gauge enables the railway builder to sharpen his curves This is of great value in mountainous country, because the line can then follow the contours of the hills closely and so avoid the construction of heavy embankments or costly bridges, viaducts, and tunnels

Some of the narrow-gauge railways in Great Britain have often been regarded, quite unjustifiably, as mere 'toy railways', whereas, in point of fact, they are business concerns performing useful and profitable work Take, for example, the Festiniog Railway in North Wales It has a gauge of only 1 foot 11½ inches and was opened for slate traffic in 1836 It was the first narrow-gauge public railway in the world Steam traction was introduced in 1863 and passenger traffic began two years later Throughout each year this little railway carries a heavy traffic in slate from the quarries at Blaenau Festiniog to the sea at Portmadoc The line has an even gradient throughout its length, in order that trains of slate may be worked down from the quarries to the coast by the use of gravity alone, the duty of the engine being to haul the empty wagons back to Festiniog

Another example of the carrying capacity of an exceedingly narrow gauge is provided by the Ravenglass and Eskdale Railway in south-west Cumberland This railway was originally laid as a mineral line to a gauge of

2 feet 9 inches  It failed financially, and in 1916 it was converted to a gauge no wider than 15 inches in order that it might be made into a miniature railway, with trains to be hauled by miniature locomotives  After some years of experiment and improvement this little railway—which claims to be the smallest public railway in the world—became a successful commercial venture  Light, open passenger coaches are used with locomotives which are capable of handling trains of 200 passengers and upwards (see Plate 4)

Heavy traffic in broken stone also passes over this railway, for the working of which powerful petrol tractors are employed  For this stone traffic wagons have been designed each holding 6 tons of broken stone and weighing empty 2½ tons  On this narrow track, with light passenger trains, a speed of 36 miles per hour has been reached with perfect safety and smoothness  These few details give some indication of the capacity of the 15-inch gauge, which is, perhaps, the narrowest gauge on which a public railway can properly be operated

Another and more ambitious 15-inch gauge railway was opened in 1927 along the south coast of Kent, between Dungeness, New Romney, Dymchurch, and Hythe  On this line passenger trains at times are made up of 17 to 20 vehicles, with seating accommodation for 130 to 160 persons  Each engine with its tender weighs rather over 8 tons, and maximum speeds are attained of over 30 miles per hour  In the first month of its working this diminutive railway carried 7,500 passengers—a striking illustration of the capacity of a 15-inch gauge line

The title of this chapter, it may have been noticed, is 'Railway Gauges'  So far we have been dealing only with the gauge of the track, usually known as 'the gauge' or 'the standard gauge', but there are other important gauges which must be mentioned  There is, for example, what is called the 'loading gauge'  At the exit of the lines from a railway goods yard a strip of steel in the

shape of an arc is suspended directly over the track from a right-angled structure, consisting of an upright post and an arm, very like a gallows in appearance This is the loading gauge Its function is to show whether or not the tops of the loads which have been put on out-

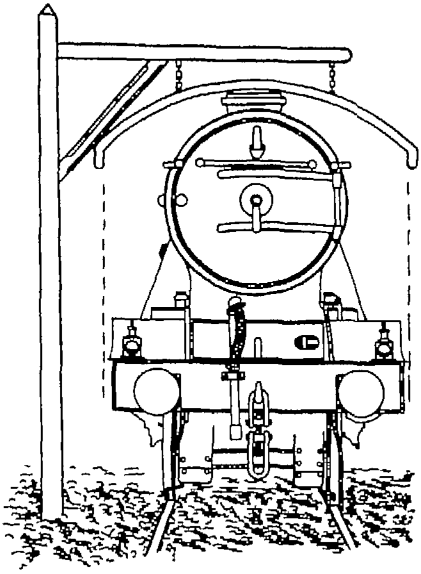


FIG 8 Loading gauge

going wagons will clear the bridges and tunnels *en route*

This loading gauge is definitely related to and, indeed, derived from another gauge, known as the 'construction gauge' This latter gauge decides how near to the track, either above it or beside it, constructions such as bridges, tunnels, signal boxes, platforms, &c , may be erected Obviously, the dimensions of locomotives and coaches must be within the dimensions of the construction gauge if the rolling-stock is not to foul the bridges and other structures along the route

.We shall see later, when we come to consider the

design and building of locomotives, carriages, and wagons, that the construction gauge, which we have inherited from the early engineers, has imposed severe restrictions on the designers of to-day. This is one of the disadvantages of pioneering. The utmost height above the rail track to which a British locomotive may be built is 13 feet 6 inches, and the maximum width is 9 feet 6 inches. On some British routes, indeed, there is not even as much as 13 feet 6 inches in head room above the tracks, so that there is a modern tendency still further to reduce the height of the latest standard locomotives by as many inches as are necessary to enable them to run over all the main line sections of the railway systems concerned.

In almost every other country of the world the construction gauge is larger than that of Great Britain, with the consequence that bigger rolling-stock may be built. In South Africa, for example, even though the track gauge is only 3 feet 6 inches, some of the passenger locomotives used are bigger and heavier than the biggest in Great Britain. This is possible because the construction gauge in South Africa is both higher and wider than in Britain.

Similarly, on the continent of Europe locomotives and coaches can be built in general to a height above rail of 14 feet and to a width of 10 feet 2 inches. One consequence of this is that, although English rolling-stock can be run over the railways of the Continent, as it was run over the railways of France during the Great War, the converse is not possible. The wagons which are used for 'through-running' between continental countries and Britain by the Harwich–Zeebrugge train ferry were specially built for the purpose and conform to the clearances of the *British* construction gauge.

On the chief American railways the construction gauge makes it possible to build rolling-stock, including locomotives, to a maximum height of 16 feet above the rails and to a width in proportion to this height. This

is why the American railways may boast of having the largest locomotives, coaches and wagons in the world

Let us consider a few figures to illustrate the influence of more liberal construction gauges Among the most powerful express engines in Great Britain are the 'King' class engines of the G W R The weight of the engine in working order is 89 tons and of the tender 46 tons 14 cwt, making a total weight of 135 tons 14 cwt, the heaviest axle-load being 22½ tons They have a tractive effort of 40,300 lb In the U S A engines weigh as much as 160 tons without the tender and develop a tractive force up to 65,000 lb There are tenders in America having an over-all length of nearly 45 feet and weighing 170 tons fully loaded The coal capacity of these tenders is 28 tons and the water capacity 22,090 gallons, whereas the heaviest tender in Great Britain weighs 56 3 tons and holds not more than 9 tons of coal and 5,000 gallons of water Similarly, many tenders of continental locomotives are built to carry from 10 to 12 tons of coal and from 7,000 to 8,000 gallons of water

It is interesting to recall that, when the idea of the construction of the Channel Tunnel was revived at the end of the war, the question of enlarging the British railway construction gauge on those routes that would be chiefly affected by the tunnel was carefully examined, but the cost was found to be so enormous as to make the project impracticable Nevertheless, he would be a bold man who should say that under no circumstances would it be feasible to enlarge the British railway construction gauge The question is ultimately one of balancing the economic advantages to be gained by the enlargement against the colossal capital cost involved

Although narrower gauges mean cheaper construction and maintenance, they also mean slower trains of small capacity It is, however, the cramped construction gauge, rather than the narrow track gauge, that is the most serious impediment to the use in Great Britain of still larger locomotives and carrying vehicles Putting

it in another way, if the construction gauge of this country were substantially enlarged it would be practicable to enlarge proportionally the dimensions of the rolling-stock, even if the rail gauge remained at its present limit of 4 feet 8½ inches What the railway engineer, however, desires above all is uniformity of gauge, so that through-running may be facilitated

CHAPTER IV

# TUNNELS, BRIDGES, AND VIADUCTS

It was pointed out in the previous chapter that in planning a railway the first things to be decided are the route to be followed and the gauge to be adopted Next comes the question of what engineering structures, such as tunnels, bridges, and viaducts, will have to be constructed for the particular route chosen

Here, again, we must notice that such decisions are necessarily governed by economic considerations, except, of course, where questions of military strategy override the economic argument In other words, those who are responsible for laying down a new railway route must count the cost and ask themselves from time to time, Will it pay to incur this or that particular expenditure? This means that some idea must be formed of what kind and what volume of traffic the line may be expected to carry If it seems likely that the line will attract a large amount of traffic and earn a considerable profit, then, obviously, more expense may be incurred in the construction of it than would be justified in the case of a line having prospects of yielding only a slender revenue

These financial or economic considerations arise, for example, when the question of shortening, or of easing the gradients of, an existing route is considered The expenditure will be justified roughly by the saving that the improvements are likely to make in the cost of working the traffic When, therefore, we come across a very long tunnel or enormous bridge, or a long and lofty viaduct, we may be sure that, before any one of them was built, somebody counted the capital cost involved and compared it with the savings in working costs likely to be gained thereby

Let us look at some of the enormous structures that have been erected from time to time in the evolution of

railways The G W R spent about £2,000,000 on constructing the Severn Tunnel, which is Britain's longest tunnel and also the longest *under-water tunnel* in the world In conjunction with the shortened route through Badminton, the tunnel has cut 25 miles off the route previously followed to South Wales, and the gradients and curves have been considerably eased Thus very great economies were made possible—economies both in regard to time and to the cost of working the passenger and freight traffic passing between London, on one hand, and the industrial centres of South Wales and the port of Fishguard, on the other

Tunnelling is, in general, a costly business—so costly, indeed, that tunnels are usually avoided if an alternative route is possible Most of the world's longest tunnels have to be lined throughout with masonry, and only rarely—e g in the case of tunnels bored through the hardest rocks—is it possible to dispense with the lining Reference has already been made to the Simplon Tunnel In this case even a lining of masonry was not enough As the bore went deeper and deeper under the mountain, the pressure of the overlying rocks became so enormous that it threatened to crush the tunnel lining, and, consequently, the lining had to be strengthened with steel reinforcements

Two difficulties that are encountered in driving the longest tunnels are those of high temperature and flooding Speaking generally, the temperature rises in proportion to the depth of the workings below the surface In the boring of the Simplon Tunnel, for example, the temperature rose to a maximum of 127° F In order to enable the workers at the face to carry on, it was necessary to pump into the workings supplies of air cooled by being passed through sprays of ice-cold water

Water, however, is usually the greatest of all enemies of tunnelling During the making of the 4⅛-mile bore of the G.W R under the River Severn, water broke into the workings This water came from three sources—

from the river bed, from the ends of the workings (as a result of the tidal wave known as the 'Severn Bore'), and, thirdly, from a vast underground flow of water known as the 'Great Spring'. It was necessary from time to time to employ divers in order to carry on the work, and when the tunnel was at last finished it was necessary to install powerful pumping machinery to keep down the percolation of water into the tunnel from the Great Spring To-day water is being pumped out of the tunnel at the rate of about 20,000,000 gallons daily

Sometimes, however, the railway is required to run only a little below the ground-level, and then a construction known as 'cut and cover' is adopted Unlike the true tunnel, this construction does not involve boring The 'Inner Circle' of the London Metropolitan and Metropolitan District Railways (except those sections which come out into the open) is of this character A cutting was originally excavated throughout the route to the level of the railway, the cutting was then roofed over, and in many places buildings and streets were built on the roof—hence the term 'cut and cover'

The construction of the deep-level tubes of the London 'Underground' system, however, is a very different story Here the aim was to go deep, not only to avoid disturbance to the buildings above ground, but also in order not to interfere with the tangle of gas, water, and electric mains, telephone conduits, sewers, and drainage pipes which exists below the surface of London The actual depth of the tubes below ground varies from place to place, but, on the average, it is about 90 feet The first underground electric railway in the world was the City and South London Railway, which was opened in December 1890, and ran from King William Street via the Elephant and Castle to Stockwell

The subsoil of London is largely clay, and the actual boring of the tubes through the London clay has usually been done by what is known as the 'Greathead Shield'

method (or by a modification of it)—so called because it was first developed by Greathead, an engineer

The shield employed is a cylinder of steel, rather like the barrel of a huge drum It is of the same diameter as the tunnel to be bored Just inside it is a circular steel cutting-edge By means of hydraulic pressure the cutting-edge is forced slowly forwards into the face of the clay As the cutting-edge moves forward, navvies shovel away the earth dislodged Next, inside the shield itself, the tunnel proper is built of arc-shaped, cast-iron segments bolted together The shield is then moved forward, and the space between the completed section of the cast-iron tunnel and the top, bottom, and sides of the excavation is filled in by 'grouting'—i e by forcing liquid cement into the space under pressure

In a later development of this method a rotary excavator is employed (see Plate 8) In this apparatus there is, instead of the cutting-edge, a wheel of the same diameter bearing on its spokes large cutters When the shield advances these cutters revolve against the exposed face of the earth and thus make the work of the navvies easier

In mountainous districts, such as Switzerland, it is usually hard rock that has to be pierced for the tunnel bore In this case a means very different from the Greathead Shield is employed The rock has to be drilled with rock-drills and then blasted away, by dynamite or other explosive, step by step, until the tunnel way is completed

It may be noticed here that the Simplon Tunnel (12¼ miles) took eight years to complete and cost £3,000,000 The St Gotthard Tunnel, 9¼ miles long, also took eight years to complete and it cost 2¼ million pounds In Great Britain, as far as length goes, after the Severn Tunnel there come next, in order Totley Tunnel, on the L M S R (3 miles 950 yards), Standedge Tunnel, also on the L M S R (3 miles 60 yards), and Woodhead Tunnel, on the L N.E R (3 miles 13 yards).

Coming now to the question of railway bridges, we may note that bridges of large span are almost invariably required to carry the railway across waterways Hence, one of the first considerations in these cases is whether there are facilities for the erection of intermediate piers to support the bridge This depends, in turn, upon the depth of the water to be crossed and the nature of its bed—for example, whether firm or shifting

When Robert Stephenson, the only son of George Stephenson, was planning what is now the L M S R main line to Holyhead, he found that the Menai Straits barred the way of his line from the mainland to the Isle of Anglesey He got over this obstacle by building the famous Britannia Tubular Bridge, which was opened in 1850 This bridge consists essentially of two tubes of wrought iron, rectangular in section, each being 1,510 feet in length and about 4,680 tons in weight The two tubes are set up side by side, one carrying the down line and the other the up line Fortunately the straits are not very deep, and three supporting towers were built in the bed of the channel, the two main spans between the towers being 459 feet long

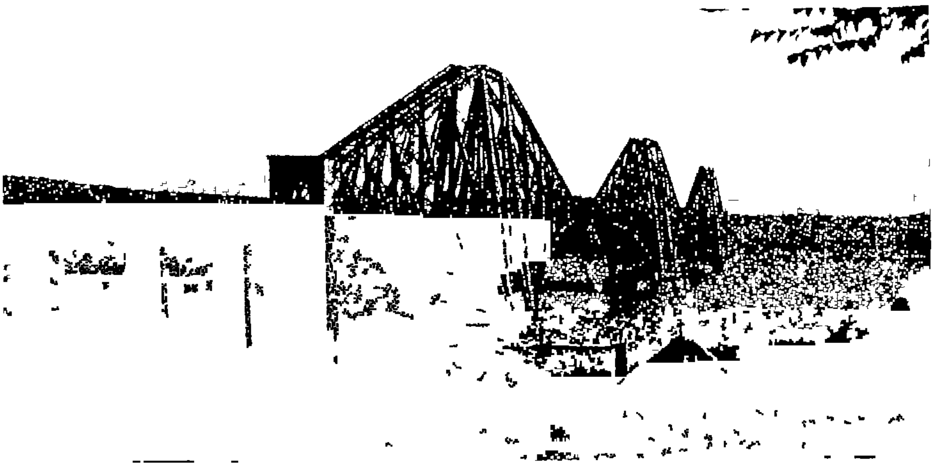
Similarly, when Brunel was planning the route to be followed by the main line of the G W R from Devon westwards into Cornwall, he had to deal, just beyond Plymouth, with the very serious obstacle of the River Tamar, which here is 1,100 feet broad and, in the centre of its channel, 80 feet deep He designed the famous Saltash Bridge, for the construction of which he sank a central pier in the river by means of caissons By this device he halved roughly the length of span required The actual width of each of the two great spans is 455 feet Saltash Bridge was completed and opened in 1859, and it still stands, nearly eighty years after, almost unaltered, carrying the far heavier locomotives and rolling-stock of these days

Another instance in which free use is made of sup-

porting piers, because of the moderate depth of the water, is the Tay Bridge It has a total length of 2 miles, in the course of which there are no fewer than 85 spans between the piers, the longest of them measuring 245 feet each The first Tay Bridge was the scene of one of the most calamitous accidents in British railway history On one stormy midwinter night, in 1879, the whole of the centre of the bridge was blown down while the night mail train was passing over, the train pitched into the river and every soul on board was drowned

In more recent times there has been a growing tendency to use the 'cantilever' construction in the building of the biggest bridges The cantilever is essentially a bracket, that is to say, a structure overhung from a base which is fixed The principle of the cantilever was applied centuries ago to primitive forms of bridge in Japan, in India, and in China The bracket that is used in architecture for supporting cornices, balconies, and even stairs is a cantilever By applying the cantilever principle to bridge construction, the quantity of steelwork required is considerably reduced, as compared with that needed by an ordinary girder bridge of corresponding span One of the most famous of these cantilever bridges is the Forth Bridge, which carries the east coast route of the L N E R system across the Firth of Forth

The Forth Bridge was designed as far back as 1883 Three great cantilever towers have bases so broad that the enormous weight of each tower keeps it stable under all conditions, so that there need be no fear of a repetition of the Tay Bridge disaster The central tower is firmly founded on the island of Inchgarvie, and each of the vast main openings measures 1,710 feet clear, the underside of each span being 157 feet above water-level The bridge is 1½ miles long, the cantilever section being exactly 1 mile in length, the high approach viaducts making up the rest The Forth Bridge cost no less than 3 million pounds, but, together with the Tay Bridge,

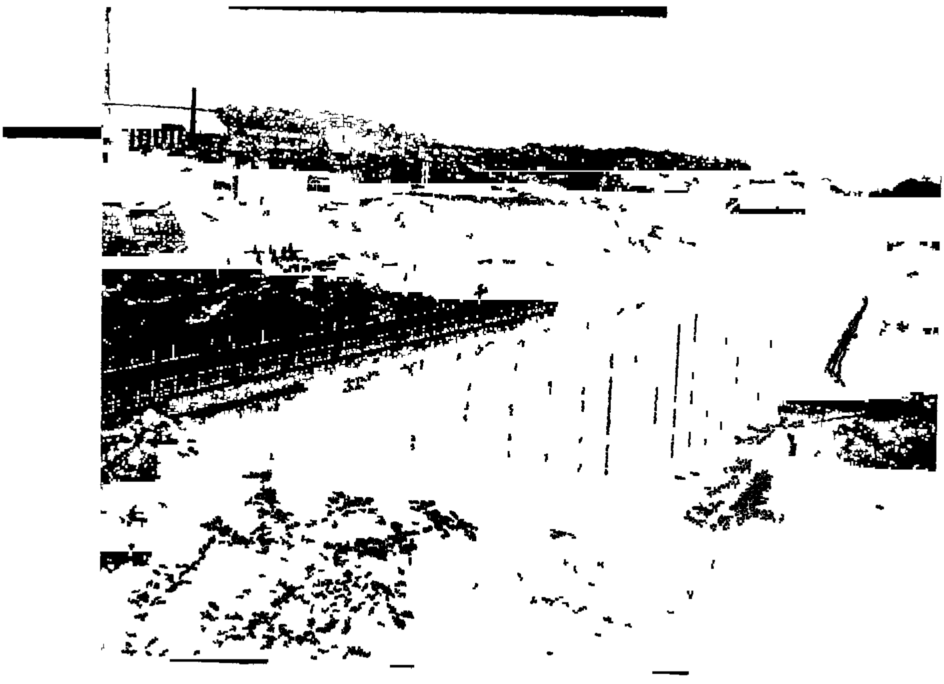


By courtesy of L N E R

1 Forth Bridge
2 Quebec Bridge, Canadian National Railway
3 Lethbridge Viaduct, Alberta, on the Canadian Pacific Railway

Landwasser Viaduct, Rhaetian Railways, Switzerland
*Photo Albert Steiner St Moritz*

Lockwood Viaduct, near Huddersfield
*By courtesy of L M S R*



it has made the east coast route north of Edinburgh practicable and profitable Before these two bridges were built through working up the east coast of Scotland was so very difficult as to be practically impossible

Of other great cantilever bridges in the world we cannot do more than mention a few There are the Sukhur Bridge over the Indus, in India, spanning 790 feet, and the famous Quebec Bridge, which carries the Canadian National Railway across the St Lawrence just above Quebec (Plate 6) This latter bridge has one main span, with a clear opening of 1,800 feet, thus exceeding the 1,710-feet span of the Forth Bridge Nor must we forget the Sydney Harbour Bridge in Australia, and the still more recent Storstrom Bridge, opened in Denmark in September 1937 This last-named bridge is 10,535 feet, or just under 2 miles, long It is the longest bridge in Europe, beating the Tay Bridge by about 8 feet It is only in part of cantilever construction, and it carries not only the railway but also an 18-foot road and a pathway for cyclists

Across many inland valleys railways have been carried by means of large viaducts, built of brick or of masonry For such viaducts good solid foundations are essential on which to base the piers Among British viaducts which may be mentioned there is the Welwyn Viaduct, on the L N E R main line, 21½ miles from King's Cross This viaduct is of masonry, and its 40 arches have an average span of 40 feet, the total length of the viaduct being 1,560 feet The maximum height above the floor of the valley is 100 feet Another and typical British masonry viaduct, of impressive appearance, is the Lockwood Viaduct of the L M S R near Huddersfield It has 36 spans in a total length of 1,407 feet, and at its highest point is 129 feet above the valley

Some of the railway viaducts of Switzerland are marvellous feats of engineering An extraordinary example is the Landwasser Viaduct of the Rhaetian Railways It is planned on a curve and has also a rising gradient of

1 in 50, each of its six arches has a span of 66 feet, the viaduct being 426 feet long At one end the arch springs directly from the face of a sheer precipice, the rail level being 213 feet from the floor of the valley (Plate 7)

In the building of a new route, as each of the cuttings, embankments, tunnels, bridges, and viaducts is finished, so the permanent track is laid along the route At the same time, all the stations and depots along the line are erected, together with the signals and signal-boxes, and the sidings and goods-yards also make their appearance

Before a railway can be formally opened it must be inspected In Great Britain this is done by an officer of the Ministry of Transport Bridges, embankments, and viaducts are tested, the whole of the signalling system is thoroughly examined, and only when all is certified to be in order and the route pronounced safe for traffic is permission to open given The construction engineer has now done with it and it becomes the care of the maintenance engineer, whose duty it is to see to its upkeep

CHAPTER V

# THE TRACK

We have seen in the introductory chapter something of how the modern track or, as it is often called, the 'permanent way' was evolved from the wooden track consisting of oak rails laid upon blocks of wood. The oak rails were superseded by cast-iron rails, and they in turn gave way to rails of malleable iron, which, finally, were supplanted by steel rails. We need not go into the details of all these changes. Let us come to a little closer examination of the permanent way of to-day.

Everybody who has travelled on a railway is more or less familiar with the main features of the track on which the trains run. There are, first, the wooden sleepers, which are usually laid transversely to the track, although sometimes they may be laid parallel to its length. These sleepers rest upon a carefully prepared foundation of broken stone, known as ballast. Cast-iron 'chairs', screwed firmly into the sleepers, support the rails, and timber or spring-steel wedges, named 'keys', hold the rails firmly in the chairs. The ends of adjoining rails are secured by means of steel plates, known as 'fishplates', which are bolted together through the rail-ends.

Since the early days of railways there have been many changes in the form and weight of the rails used. As to the form, if we look endwise at the rail of to-day we shall see that the upper part or head of the rail has a larger cross-sectional area than the lower part or foot. This type of rail is known as a 'bull-headed' rail. The advantage of a rail of this design is that the head may safely be allowed to wear down under heavy traffic, until it is roughly equal, in cross-sectional area, to the foot. When this condition is reached it is time for the rail to be renewed.

It is, of course, owing to the pounding and rubbing

action of the wheels that the upper surface of the rails is gradually worn away On a straight track the wear is chiefly on the top of the head, but on sharp curves the wheel-flanges of the vehicles bear heavily against the outer rail of the curve, with the consequence that these outer rails wear away at an angle This wearing effect is known as 'side-cutting' •

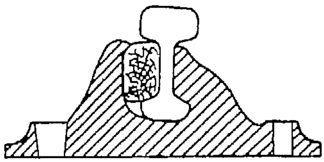


FIG 9 Bull-headed rail Chair for timber sleeper and key

There is one important difference between the type of railway track in use on the Continent and that used in our own country The continental railways do not employ chairs in which to hold the rail The lower part of the rail is spread out into a flat foot, which rests directly on the sleeper, no chair being needed This type of rail was introduced by Charles Vignoles, by whose name it is often known In the early days of railways it came into favour because it could be spiked down directly on the sleepers, and, therefore, by eliminating chairs, track-laying was made easier This was, of course, a very great advantage to railway pioneers in undeveloped countries

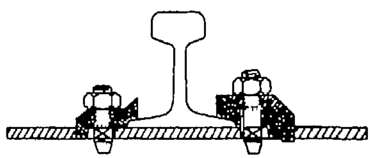
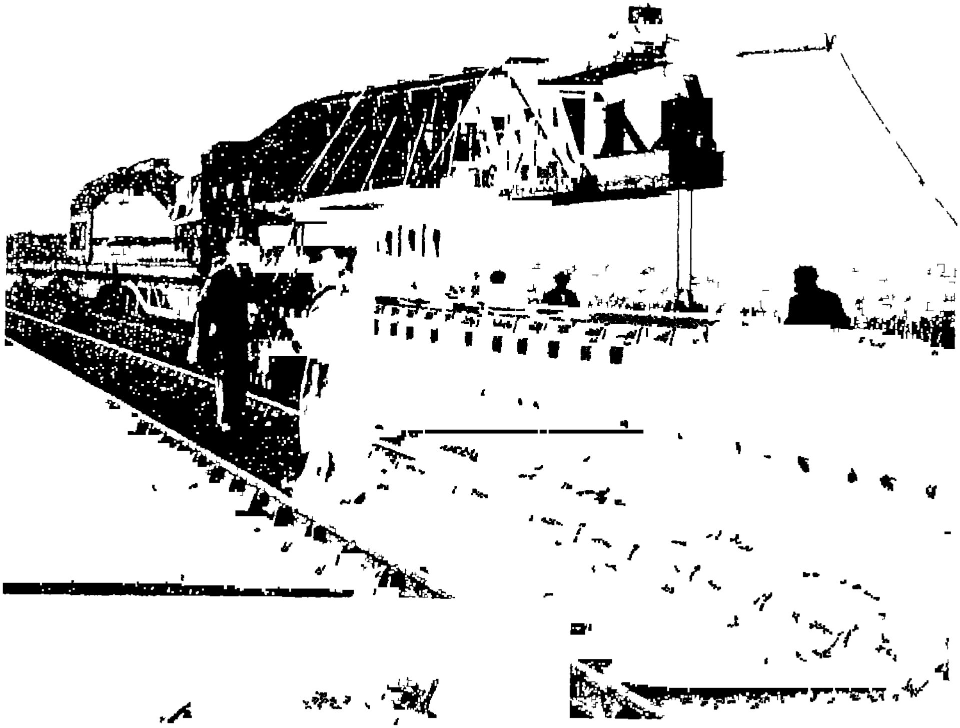


FIG 10 Vignoles rail Clip and bolt fastening for steel sleeper

The flat-bottomed, or Vignoles, rail has become standard for railways in nearly every other country but this Nowadays, however, a plate of steel, called a 'sole-plate', is usually placed between the flat-bottomed rail and the sleeper The sole-plate, like the chair, serves to spread the weight of the moving load over as large an area of the sleeper as possible and thus to increase the life of the sleeper

There has been a good deal of argument as to which of the two tracks—the bull-headed rail track or the flat-



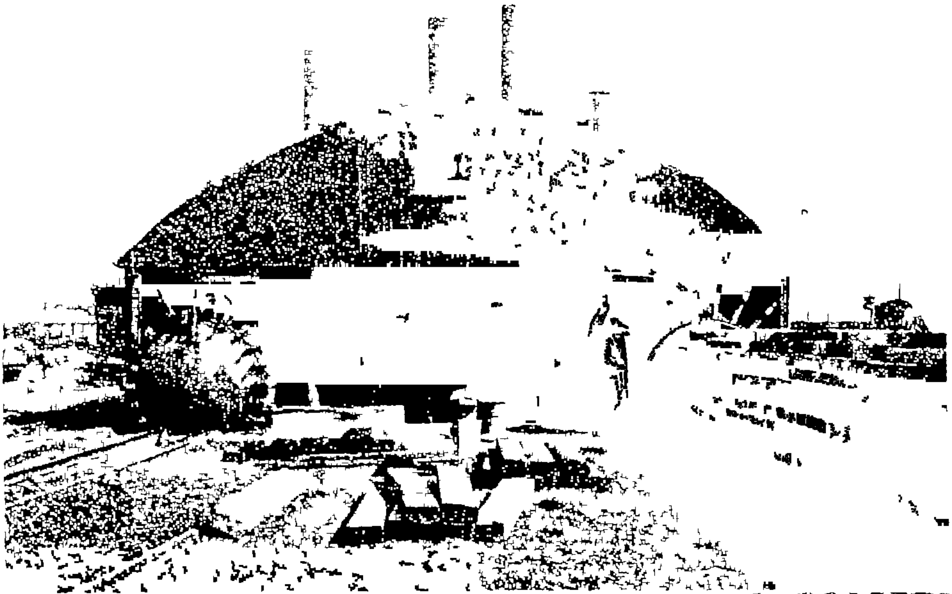
Track-layer at work on a section of the L N E R

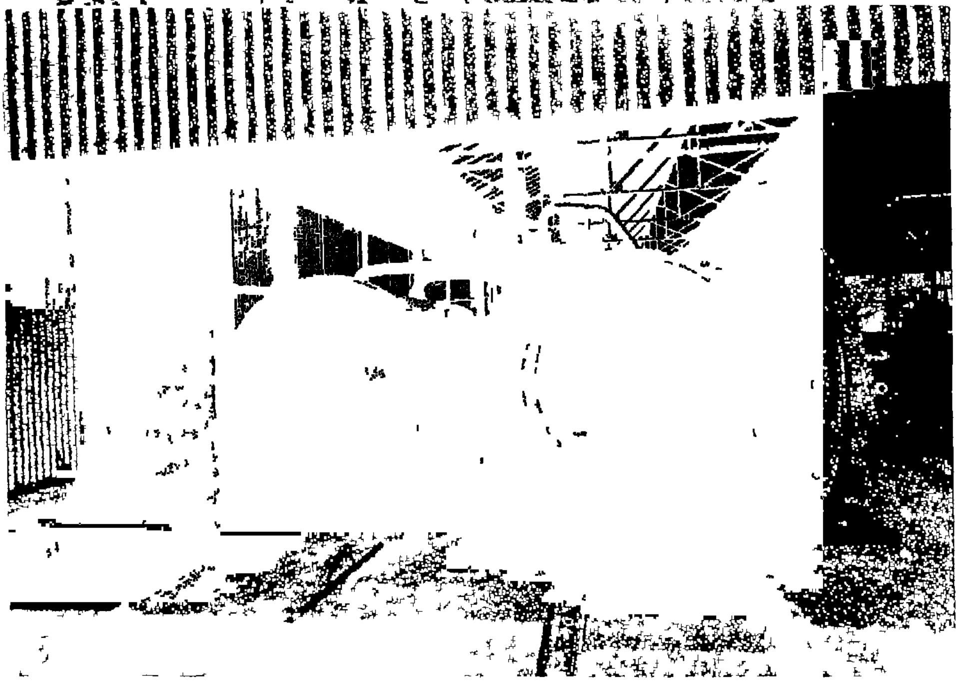
*Photo Topical*

Rotary excavator

*Photo London Passenger Transport Board*

PLATE 9





*Above* Sleepers passing into creosoting cylinders, Beeston Yard (Notts )
*Below* Cylinder full of sleepers at Hayes Yard (Middlesex)

*By courtesy of the L.M.S and G W Railways*

bottomed rail track—is the cheaper to lay and to maintain, and, also, which of the two provides smoother riding. Incidentally, it may be noticed that a patent was once taken out for hollow rails, which were to be filled with hot water in cold weather, the idea being to prevent ice forming on them and causing the wheels to slide! This fantastic idea was never put into practice.

With the development of railways the weight and the speed of trains have steadily increased, and so it has been necessary to increase in proportion the weight of the rails used. On the main lines of British railways the standard rail weighs 95 lb. per yard of length. For branch lines 85-lb. rails are used. At certain places, like the Forth Bridge, specially designed rails of a weight greater than 100 lb. a yard are used. The greater the weight and strength of the rails, the greater the factor of safety. It is interesting to note that the rails originally laid on the Stockton and Darlington Railway weighed 28 lb. per yard, so that the modern main line rail is nearly 3½ times as heavy.

What about the length of the rail? The joints between the rails are the weakest parts of the track. They are the cause of the jolts that impair the smooth running of trains. They increase resistance, call for more power from the engine, and increase the running costs. Obviously it is an advantage to reduce the number of joints by the use of longer rails. This is the main reason why the length of British rails has increased gradually from about 15 feet (which was the length adopted by George Stephenson when he constructed the Liverpool and Manchester Railway) up to 45 feet, and latterly to 60 feet. Another advantage of using longer rails is that the number of fishplates required for a given length of track is reduced.

In 1937 both the L.M.S.R. and the L.N.E.R. laid 120-foot rails, which were produced in one piece from the rolling mill. In Australia, after the rails have been

laid, they have been welded, end to end, up to lengths of over 200 feet Recently the Southern Railway relaid the entire length of Quarry Tunnel, on the Brighton main line, near Merstham, with 180-foot rails Each of these rails was produced by welding together three 60-foot rails The practice of welding together the ends of the rails is also being extensively applied in the London tube railways, one object being the reduction of noise In Germany a rail length of 30 metres (98 feet 5 inches) is now standard

In the making of rails for such places as crossings and junctions, where the wear of the rails is exceptionally rapid, alloy steels are sometimes used The most frequently used of these is manganese steel, which contains a very much larger percentage of manganese than does the standard steel used for the ordinary rails There is no steel equal to manganese steel in its power of resisting the abrasive action of the wheels, with the consequence that it has a 'life' many times longer than that of ordinary steel It is, however, very costly, and consequently it is used, as a rule, only for those parts of the track where, because of exceptionally heavy traffic, ordinary rails would wear away very rapidly

What is the life of the modern steel rail? This depends, of course, upon many circumstances, such as the weather conditions of the neighbourhood in which the rails are laid, on the curvature and the gradient of the line, and on the density of the traffic Near Widnes, in Lancashire, the rails have a shorter life than have rails elsewhere because of the fumes emitted from the numerous chemical factories in the neighbourhood of that town Similarly, in damp tunnels or on steep down-gradients where goods trains run usually with the brakes applied, the life of the rail is substantially reduced On the whole, it may be taken that the average life of rails on the main lines of this country is about 21½ years, but the rail is not necessarily done with then After the expiration of that period about two-thirds of the rails

continue to lead a useful, if unobtrusive, life in sidings and on branch lines, where they have to bear only light traffic The worn-out sleepers are used for fencing or other purposes, and, when at last their useful life is ended, they are used for firewood

Coming now to the chairs, each chair has a broad rectangular base, in order that the weight of the moving train may be spread over a large area of the sleeper The seat across the base of the chair is curved, and on it the rail rests between two upstanding jaws, the inner jaw being lower than the outer The inner jaw fits snugly into the middle of the rail But between the rail and the outer jaw there is a space, into which a wedge or 'key' (usually made of oak or of teak, but sometimes of spring steel) is inserted and driven home with a heavy hammer, so that the rail may be held tightly between the jaws of the chair When the rails are placed in the chairs they are canted slightly, so as to lean inwards with an inclination of 1 in 20, which corresponds to the conical shape of the flanges of the wheels Not many railway passengers notice that the rails are not quite perpendicular

We may consider next certain features of the sleepers to which the chairs are secured The sleepers have a double duty first, to tie together, at the correct distance apart, according to the rail gauge chosen, the two rails of the track, and, second, to spread the weight of the trains over the foundation of ballast

By far the greater number of the sleepers employed in this country are made of timber from the Baltic or from Archangel In service these sleepers are necessarily exposed to all kinds of weather, and, in order that they may last as long as possible, they are saturated with creosote before they are put on to the track

The rough timber sleepers are first of all seasoned in the open air in great stacks From the stacks they are fed, one at a time, into a shute or slide, and pass on to an

endless moving chain This chain carries them straight into the shop on to the adzing machine As the timbers pass through this machine, flat surfaces or 'seats' are cut in those places where the chairs will be eventually fastened Next, the sleepers pass on a moving belt to a boring machine, which bores, in the correct positions and at one and the same time, six holes for the screws that are to fasten the chairs to the sleeper—three holes for each of the two chairs

The sleepers are now loaded into cylindrical trucks, fashioned like metal cages, with broad bands instead of wires, each truck holding sixty sleepers These trucks, or cages, are mounted on wheels, and a train of them is run on rails into a huge cylinder—the creosoting cylinder This cylinder can hold at one time as many as ten cages containing six hundred sleepers in all When the cylinder is full, the doors are tightly closed and the air is pumped out by means of a powerful suction pump (Plate 9)

A quantity of creosote, which has been previously heated to make it sufficiently liquid, is now admitted into the cylinder, and a large volume of it is at once absorbed by the sleepers After the cylinder has been completely filled a force-pump is employed, which raises the pressure in the cylinder still farther In the course of an hour or two each sleeper will have absorbed from 2½ to 3 gallons of creosote The force-pump is then stopped, the surplus creosote is sucked out of the cylinder by means of the exhaust pump, and the process of creosoting is complete

All that is necessary now is to fasten the chairs to the creosoted sleepers The cages of sleepers are withdrawn from the cylinder at the end opposite to that at which they entered it, and the sleepers pass, again on a moving belt, to a bench known as the 'chairing bed', at which the chairs are also arriving Thus the sleepers in an endless stream enter the shop at one end and, as they travel through it, are adzed, bored, and creosoted in

turn, and meet the incoming chairs at the other end of the shop

At the chairing beds a hair-felt pad is first placed upon the sleeper, so that it will be between the chair and the sleeper This pad forms a kind of cushion to the blow of the moving train on the sleeper and thus helps to reduce noise The sleepers pass in turn to screwing machines, which drive home the galvanized steel screws to bind the chair securely to the sleeper

From these machines the creosoted sleepers with their chairs firmly secured pass on a conveyer directly into wagons on the yard track, and thence they are sent wherever they may be required By having the sleepers ready chaired at the place at which they are to be laid a great deal of time is saved in the actual laying of the track

Creosoted wooden sleepers have the virtues that they are tough and elastic and have only a very slight tendency to shift their position But wood is not the only material of which sleepers can be made Iron sleepers are widely employed in some parts of Europe, while in tropical countries they are often indispensable because of the attacks made by insects upon wooden sleepers

A good deal of experimenting has taken place also with the use of steel or concrete as the material for sleepers One difficulty of metal sleepers is that the friction against the ballast is very much less than that of wooden sleepers, so that the metal sleepers are more liable to shift their position, also, of course, it is not so simple an operation to fasten the rails to metal sleepers as to wooden ones

The main difficulty in the use of concrete sleepers is that the concrete is liable to shatter and break up under the hammering effect to which the track is subjected by heavy trains Still, supplies of timber are not inexhaustible, and, in view of the possibility of a shortage of timber, it is more than possible that some form of

steel or concrete sleeper will be developed that may eventually displace the timber sleeper

Let us remind ourselves here that the wheels of the train are supported by the rails, the rails rest upon the chairs, the chairs are fastened to the sleepers, and

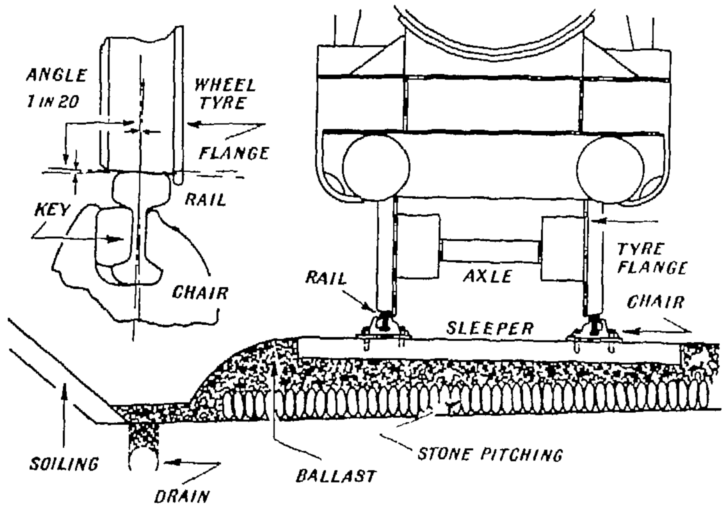



FIG 11 Cross-section through permanent way

the sleepers rest upon, and are embedded in, the ballast Thus we see that the ballast is the foundation of the permanent way. Good ballast is the first thing necessary for a good track The engineers whose duty it is to look to the upkeep of the permanent way insist that the first and last requisite is a perfect system of drainage

It is this primary consideration that decides what material shall be used for ballasting the track It must be laid to a sufficient depth in order to distribute evenly the weight of a passing train over the whole soil beneath it It must not be too rigid, but elastic enough to give the smoothest possible running, and it must grip the sleepers sufficiently to prevent the least horizontal movement Especially must it be of such a character as not

to be absorbent of moisture, but to allow rain to drain off it rapidly

Of all the various materials which are used for ballast, broken basalt or broken granite is the most suitable These materials are, however, costly Limestone, which is cheaper, is often used Of recent years a very effective and much cheaper substitute has been found in blast-furnace slag This material has proved useful not only for railway ballast but for road metal, with the consequence that all over the country those mountains of waste slag, which were eyesores for so many years, have been gradually melting away as the material has been broken up and put to use More broken slag is now used for ballast than any other material

In the early days the ballast to be laid on the track was first taken to the site in ordinary wagons and unloaded into heaps spaced at suitable intervals beside the track Gangs of platelayers armed with shovels then spread the ballast over the track, tucking it under the sleepers until a firm foundation was made In these days ballast trains are employed They consist of wagons that can discharge the loose stone directly on to the track through the floors of the wagons As the engine draws the ballast train slowly forward, a plough very like a snow-plough, which is fixed in front of the brake van, spreads the ballast thus discharged from the wagons The platelayers then finish the operation (Plate 10)

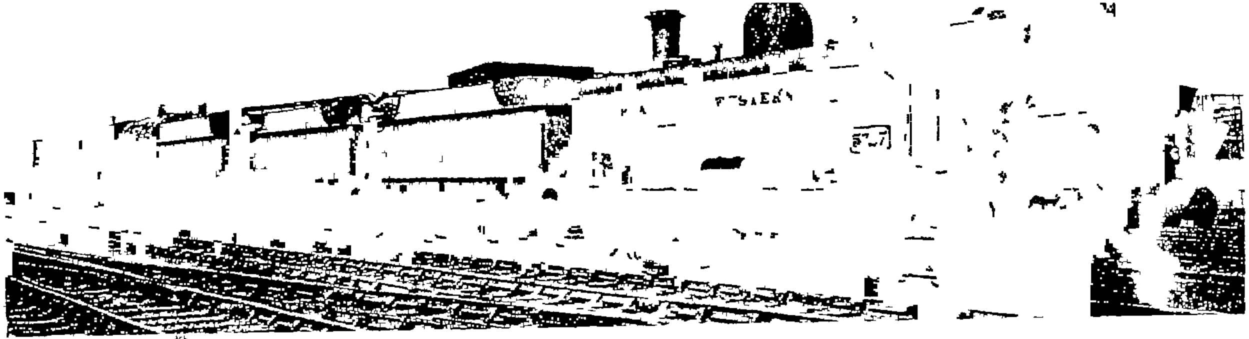
One modern development in the upkeep of the permanent way is the use of welding processes Most railway travellers are fairly familiar with the crossings or forks of the permanent way where one track diverges from another These rail crossings wear away fairly rapidly They are costly to make and also to maintain In order to reduce the expense incurred in maintaining these joints and crossings, welding processes are now being used, so that new metal can be welded on to the worn parts of the crossings in such a way as to build up the rails to their original form

Moreover, this work can be done on the spot, without removing the crossings from the track  Specially trained men carry out the welding operations as opportunity occurs between the passing of trains  When the welding process is completed, the new metal thus added is ground by a portable grinding machine and 'dressed off', the result being that the repaired crossing is, in all respects, equivalent to a new one

It was pointed out previously that the rails on curves, particularly the outside rails, get side-worn much more than do the rails of the straight track  This side-wear, of course, shortens the life of the curved rails and the renewal of the worn rails is a serious expense  In order to lessen this expenditure 'curve-oilers' are installed at the beginning of the curve  The curve-oiler is a long, narrow tray containing lubricating oil and a wick  As the trains pass, the flanges of the wheels dip into this tray and come into contact with the oil-saturated wick  In this way the flanges themselves become oiled, carrying the oil with them round the side of the rail on the curve  It has been found that the use of this device has very considerably reduced the wear of the rails

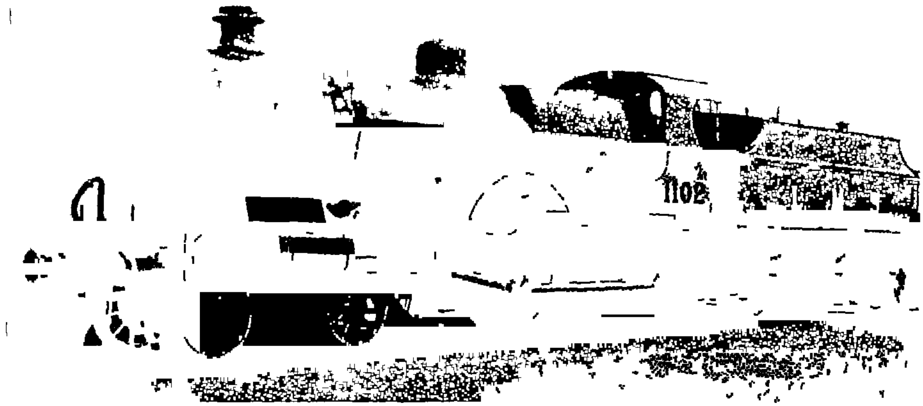
One interesting problem connected with the maintenance of the track is the question of how to keep down the weeds that tend to grow over it  Seeds, of course, are blown from fields adjoining the route, and the track forms a ready seed-bed for them  It is not merely that the growth of weeds makes the permanent way unsightly, but the ballast becomes choked with vegetable fibre from the roots, and this, of course, leads to serious troubles in drainage

Until comparatively recently the weeding was done very much as in the ordinary garden, that is, by the use of hoes, rakes, or other gardening implements  These methods, however, take time and are costly  In order, therefore, to reduce both time and cost a new method has been adopted and is being increasingly used  Large tanks, constructed so as to run on the

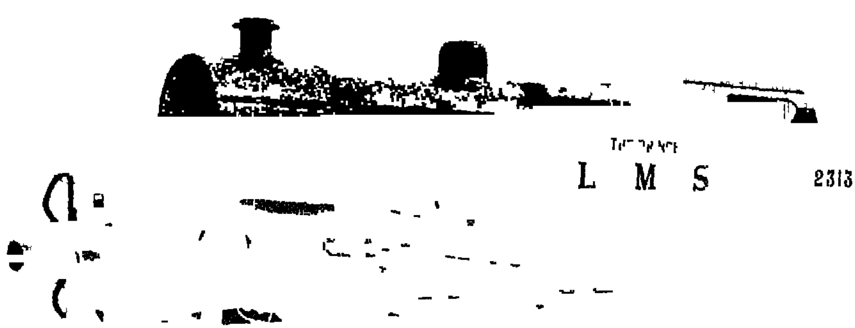


*Above* Weed-killer train on the G W R
*Below* Ballast-train on the L M S R

*By courtesy of G W and L.M S Railways*








(1) Standard 4–4–0 3-cylinder compound express locomotive
(2) 0–6–0 goods engine
(3) 2–6–4 tank engine

*By courtesy of L.M.S. and Southern Railways*

track, are filled with a solution of a weed-killer, and are fitted with pipes which can spray the solution on to the track

On the Southern Railway the latest weed-killing train is made up of eight vehicles—one goods brake van, three tenders containing enough chemical concentrate to treat 128 miles of track, three tenders containing enough water for 40 miles of track, and one six-wheeled equipment van in which the concentrate and water are mixed More water can be taken in *en route* When the train is spraying it runs at a speed of 28 miles per hour (Plate 10)

Another special difficulty with which the permanent way engineer has to deal from time to time is the blocking of the track by snow-drifts In many countries, as is well known, this constitutes a very formidable problem In Great Britain it is confined for the most part to the northern area During snowstorms and blizzards the track often becomes impassable from the drifting snow In order to keep the track clear under such conditions snow-ploughs are fitted to the fore ends of powerful engines In the northern part of Britain it is the practice to fit small snow-ploughs to the fronts of the ordinary train engines from the beginning of winter until early spring, but under severe winter storm conditions heavier ploughs are needed They are fitted to the fronts of powerful engines and are run as snow-ploughs simply, ahead of important trains, in order to clear the track If the drifts are deep a gang of platelayers accompanies the snow-plough, in case they should be needed to dig out an embedded engine or train

The track has, of course, to be renewed from time to time, and sometimes this renewal may consist simply of replacing worn rails by new ones Sometimes the old and dirty ballast has to be exchanged for new, and from time to time the old sleepers have to be removed and replaced by new ones The commonest of all these operations is that of renewing the track in its entirety, which is known as 'relaying'

These operations of track renewal are usually carried out at night For the work special gangs of men are employed who are expert in the particular tasks to be done One of the most recent developments is the employment of track-laying machines They were first used in America and have since been introduced into this country

Sections of the track, of the standard length of rail—45 feet or 60 feet, as the case may be—are assembled, completely equipped with the sleepers, chairs, and both rails of each section keyed in position These sections are then piled in stacks of five or six on specially equipped wagons The track-layer itself has a crane with a long jib, which can be extended well forward over the part of the track which is to be relaid One by one the sections of old track are lifted off the ballast by the jib and passed on to the wagons behind for removal A trolley, which moves on rails along the whole length of the relaying train, brings forward a new section of track to replace the old one that has just been removed, and the track-layer advances over each new section as it is laid One of these track-layers can 'relay' at a speed of about 240 yards to the hour Consequently there is a great saving both of time and of cost in track-laying as compared with the older method (Plate 8)

In the discovery of defects in the maintenance of the track use is made of a French device known as the Hallade Track Recording Machine It is a portable apparatus and is carried on the train By means of a system of pendulums, pointers are made to inscribe on a moving paper roll a continuous record of the train oscillations on a journey From the graph thus made it is easy to locate weak points in the track, due, for example, to rails getting out of alinement or to bad packing of the ballast

Whatever be the railway system, the permanent way is divided into sections, and foremen platelayers 'walk' these sections every day in order that defects may be

discovered and promptly remedied Not only is this necessary to secure safety but it is also essential in the interests of smooth running and efficient operation of trains A well-kept permanent way means economy in haulage, less wear and tear of the rolling-stock, improved comfort of travelling, and, in the long run, a reduction in maintenance costs It pays to make a first-class permanent way and to keep it in first-class condition

CHAPTER VI

# THE LOCOMOTIVE

IN this chapter we are to consider the design of the locomotive engine which is to haul the trains We shall consider the steam locomotive first, because it is still the most important type The earliest steam-engines invented were stationary engines and were used at first principally for pumping purposes The steam locomotive is essentially a mobile, self-contained power-house which obtains its energy from some form of fuel In this country the fuel is usually coal, though it may be oil, as it is in some other countries

In the case of electric railways the motors employed usually obtain their energy through overhead wires, or through conductor rails, from a stationary power-house where the electric current is generated As we shall see later, in some cases the electric current is generated on the train itself In many parts of the world, e g in Switzerland, water power is used to provide the energy required for electric traction But in Great Britain the energy required to run the railways, whether they be steam operated or electrically operated, comes from fuel, and that fuel is, at the present time, almost invariably coal

In scientific language, the steam locomotive is a machine for transforming the chemical energy contained in the fuel into the mechanical energy of motion The fundamental problem for the locomotive engineer is, therefore, how to obtain at the least cost, from a given quantity of chemical energy in the shape of fuel, the maximum quantity of mechanical energy in the form of motion In the steam locomotive this transformation of chemical energy into mechanical energy is brought about by the use of steam

The steam locomotive consists of three essential parts First, we have the firebox and boiler, which are com-

bined in one structure The fuel is burnt in the firebox and steam is generated in the boiler, and in this way the chemical energy of the fuel is transformed into the heat energy of the steam Next, there is the engine proper, consisting of cylinders, pistons, and other moving parts This engine transforms the heat energy of the steam into the mechanical energy of motion Thirdly, there is the frame, or undercarriage, which supports the boiler and into which the cylinders and the motive mechanism are built This frame, mounted on wheels, transmits the tractive force of the locomotive, by means of a 'draw-bar', to the train which is attached to it

We said above that the steam locomotive was a self-contained power-house It must therefore carry about with it supplies of fuel and water Usually these are carried in a separate vehicle, known as the tender, which is attached to the engine There is a class of engine, however—the 'tank' engine—which has no separate tender These engines require only comparatively small supplies of coal and water, which are carried on the main frames of the engines The use of the tank engine avoids the waste of power incurred in hauling a heavy tender carrying supplies in much greater quantity than is needed for the length of the journey Great Britain is a small but densely populated country, and therefore short railway journeys are prevalent That is why the tank locomotive is used on our railways to a greater extent than in any other country

In considering the design of the locomotive, perhaps one of the first details to be noticed is the arrangement of the wheels If we take a given locomotive—that is to say, an engine in which the details of the boiler, cylinders, and motion parts have been settled—we may say that the tractive work that it can do depends on the arrangement of its wheels, and especially on the number and the size of its coupled wheels This wheel arrangement is so important that it has been found desirable to have a means of describing it readily and tersely, and a

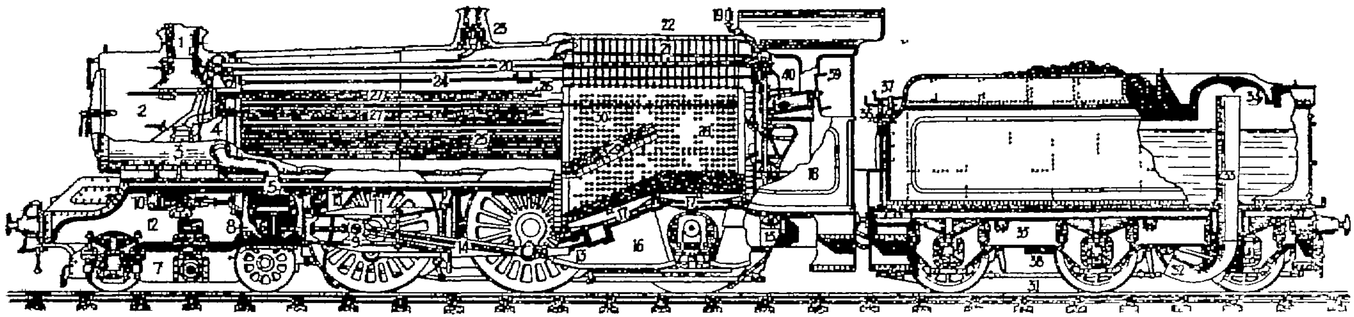


FIG 12 A modern 4–6–0 locomotive shown in section

1 Chimney
2 Smoke-box.
3 Blast pipe
4 Superheater header
5 Steam chest.
6 Piston.
7 Bogie frame.
8 Cylinder
9 Crosshead
10 Inside cylinder steam chest
11 Guide bars
12 Engine main frame
13 Coupling rod
14 Connecting rod
15 Sand boxes
16 Ash-pan.
17 Fire-bars
18 Cab side
19 Whistle
20 Regulator rod
21 Vertical stays
22 Boiler casing
23 Safety-valves
24 Longitudinal stays.
25 Fire tubes
26 Steam superheaters
27 Superheater flue tubes
28 Firebox
29 Brick arch.
30 Firebox stays
31 Brake rod.
32 Water scoop
33 Water inlet pipe
34 Deflector dome
35 Tender frame.
36 Brake handle
37 Water pick up handle
38 Vacuum brake reservoir
39 Reversing gear handle
40 Regulator

[Reproduced by permission from a colour plate in *Railway Wonders of the World*

simple numerical formula, a kind of railway shorthand, which is common to all British railways, has been devised for this purpose

Locomotive wheels are of two kinds—'idle' wheels, which merely help to support the locomotive and to distribute its weight evenly over the track, and 'coupled' wheels The latter include the driving-wheels proper (i e those wheels to which the pistons are directly connected), and also one or more pairs of wheels, *of the same diameter*, which are connected to the driving-wheels by means of coupling-rods Obviously the wheels that are so coupled together must turn in unison and are, in effect, all actuated by the motion mechanism They may, therefore, all be regarded as driving-wheels

The numerical formula or notation referred to above consists of three numbers or digits The middle digit gives the number of coupled wheels, the first digit the number of idle wheels *in front of* the coupled wheels, and the third digit the number of idle wheels *behind* the coupled wheels If there are no idle wheels in front of the coupled wheels (i e if the leading pair of wheels are coupled), then the first figure of the notation is 'o' Similarly, if there are no idle wheels behind the coupled wheels, then the third digit is also 'o' It should be borne in mind that this notation applies only to the locomotive engine and has nothing to do with the tender, if there be a tender

To take an example, the notation 4–6–0 indicates that the engine has 6 coupled wheels, with 4 idle wheels in front and none behind (i e *on each side* 3 coupled wheels and 2 front idle wheels) This is a type of locomotive, to which, for example, the L M S R express passenger 'Royal Scot' engines and the G W R 'King' class belong (See Fig 12 )

The most important figure in this three-figure formula is the central digit, which denotes the number of coupled wheels For the effect of coupling the wheels is not merely to make the wheels turn together in unison, but also to increase the weight available for 'adhesion',

in other words, to increase the grip of the locomotive on the rails It is, of course, this grip or purchase of the driving-wheels on the rails that enables the locomotive to haul the train

As traffic demands have increased, it has been neces-

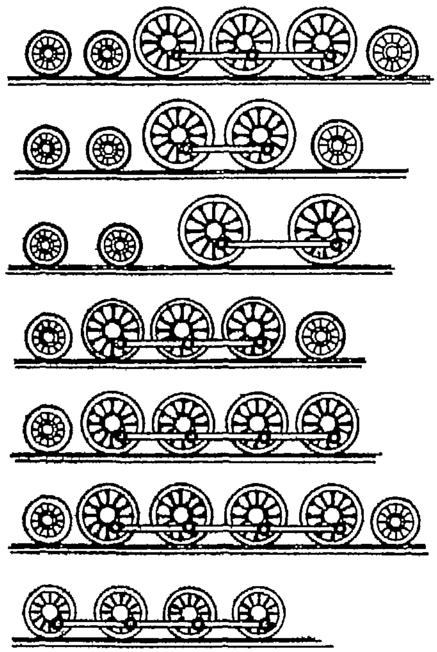



FIG 13 Wheel arrangements

sary to employ larger locomotive boilers and cylinders in order to increase the tractive power This has required correspondingly greater adhesion weight, and the coupling together of wheels has had to keep pace with these developments The greater the number of coupled wheels, the greater the adhesion weight That is why passenger locomotives have developed from the type that had only a single pair of large driving-wheels—the 'single driver', as it was called, of the nineteenth century (see Plate 2)—to four-, to six-, to eight-

and even, especially abroad, to ten- and to twelve-coupled locomotives

We cannot pursue further this subject of the notation of the locomotive What is clear, however, is that those three figures bring to the mind of the locomotive engineer an instantaneous picture of the character of the locomotive, just as a chemical formula tells the chemist a good deal about the composition of the substance it represents

The tractive work that a given locomotive can do depends, however, not only on the number but also on the size of the coupled wheels A smaller diameter increases the tractive power, a larger diameter reduces it On the other hand, for the same piston speed in the cylinder the rate of travel of the small-wheeled engine is less than that of the large-wheeled engine These facts explain why the freight engine, which is designed to haul heavy loads at moderate speeds, has driving-wheels of moderate size—about 4 feet 6 inches to 5 feet in diameter—but has all, or nearly all, its wheels coupled together, in order that the greatest possible proportion of the total weight of the engine may contribute to adhesion The express passenger engine, on the contrary, has large driving-wheels—from 6 feet 3 inches to 6 feet 9 inches in diameter—so as to make easy the attainment of high speeds

Between these two types—the freight engine and the express engine—there are engines for 'mixed' traffic, having driving-wheels of dimensions intermediate between those indicated above The tractive demands on the railway vary greatly, and that is why several and various types of locomotive are in general use on the same system Express passenger work is usually done in Great Britain by the 4–6–0 and the 4–6–2 engines For semi-fast passenger trains the type mostly used is the 4–4–0, and for freight service the most numerous class is that efficient drudge, the 0–6–0 type, often called the 'maid-of-all-work'

It was pointed out in a previous chapter that, owing to the strict limits set by the construction gauge, the utmost height above the rail level to which a locomotive may be built for running in Great Britain is 13 feet 6 inches, and the maximum width from 9 feet to 9 feet 6 inches. Now, in order to increase the tractive power of locomotives it has been necessary from time to time to increase the size of the boilers. As the diameter of the boilers has been increased, step by step, so the funnels, domes, and the other mountings on the boiler have had to shrink gradually, so that the locomotive as a whole might be kept within the limits just mentioned. To-day, in the largest locomotives the maximum limits of height and width have been reached. If, therefore, still larger locomotives are required, the only way open is to increase their length.

If, however, a locomotive is unduly lengthened it will have great difficulty, and may find it impossible, to get round the curves in the line. This difficulty has been surmounted by constructing various types of jointed or, as they are usually termed, 'articulated' locomotives. This articulation of the locomotive, like the elbow joint in the human arm, enables the locomotive itself to bend to some extent and thus to round curves. In one type of articulated locomotive—the 'Garratt' type—the locomotive as a whole consists virtually of two engines supplied with steam from a single boiler. The boiler is placed between the two engines, and the whole combination has two articulations or joints, one at each end of the frame supporting the boiler. A locomotive of this type has the advantage of using a larger boiler with two engines, and at the same time is as flexible as an ordinary locomotive in rounding curves (Plate 12).

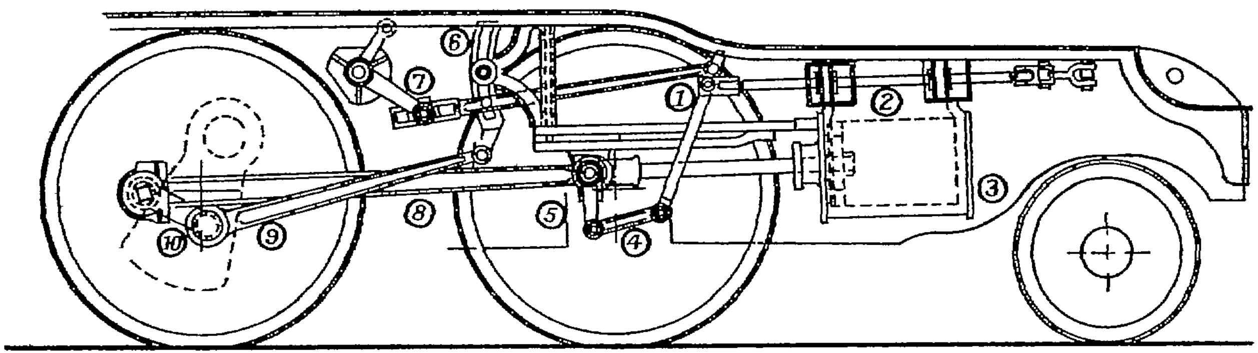
So far we have been dealing with what engineers call the 'simple locomotive'. It is, of course, the expansive properties of the steam in the cylinder which make the engine 'go'. At both ends of the cylinder are narrow openings, or 'ports', which serve a twofold purpose—

to admit the steam at the beginning of the stroke of the piston, and to release it again as the piston comes back on the return stroke These openings are controlled by valves, which regulate the passage of the steam from the steam chest into the cylinders During part of the forward stroke of the piston the steam must be allowed to enter the cylinder, thus pushing the piston forward The valve must then close the port, allowing the steam to complete its work in the cylinder by its own expansion As the piston begins its return stroke, expelling the partially expanded steam through the port by which it entered, the valve must immediately open an exit passage for the steam to the chimney Before the piston reaches the end of the return stroke, however, the valve must close the port, and thus leave a little of the steam in the cylinder, to act as a cushion for the piston as it comes to rest before moving forward once again It is the 'expansion gear', or, as it is often termed, 'valve-motion', which performs the duty of moving the valves in such a way as to allow the expansive force of the steam to do its work properly

In the 'simple' locomotive the steam from the boiler passes to the cylinders, goes through a single expansion in those cylinders, and then passes into the chimney as exhaust

But there is another type of steam locomotive, known as the 'compound locomotive', which has proved very useful In this type of engine the expansion of the steam takes place in two stages, and hence the compound engine is often called a 'double-expansion' engine High-pressure steam passes directly from the boiler into one or, it may be, two cylinders, and, after it has expanded in these cylinders, the steam then passes, at a lower pressure, into one or two cylinders of larger volume, where it undergoes a further expansion and does more work before it goes to the chimney as exhaust

It should be borne in mind that when steam expands in a cylinder its temperature falls and, because of this




1 COMBINATION LEVER
2 PISTON VALVE
3 CYLINDER
4 CONNECTING LINK
5 CROSSHEAD ARM
6 EXPANSION LINK
7 VALVE ROD LIFTING ARM
8 CONNECTING ROD
9 ECCENTRIC ROD
10 RETURN CRANK

FIG 14 Walschaert's expansion gear or valve motion

drop in temperature, the steam partly condenses, with the consequence that there is a loss of efficiency. One of the chief advantages of the compound locomotive is that the range of expansion in each cylinder is reduced, so that the fall of temperature and the condensation caused thereby are less. In order to make the fullest use of its advantages, however, the compound engine must employ high-pressure steam.

We must now note some points about the design of the boiler. It was pointed out previously that a steam locomotive is a machine for transforming the chemical energy contained in the fuel into the mechanical energy of motion. The first step in this transformation is to convert the chemical energy of the fuel into the heat energy of steam. It is, of course, the boiler which is called upon to do this vital work. Thus the efficiency of the locomotive depends very greatly upon the capacity of its boiler to boil water. That is why, with the growing need for increased power, boilers have become progressively larger.

The first aim of the locomotive designer is to have a big fire-grate and firebox for the complete combustion of the fuel, and, next, to use the utmost possible portion of the heat thus generated in heating the largest possible area of boiler surface. In the famous *Rocket* George Stephenson incorporated two most important devices. He used the escaping steam from the cylinders to provide a forced draught for the fire and thus to help the combustion of the fuel. Secondly, he increased the heating surface of the boiler by constructing it of numerous tubes. Since Stephenson's day the design of the locomotive boiler has, of course, undergone continuous improvement, but the two basic principles which have just been mentioned, the multi-tubular boiler and the draught created by the exhaust, remain.

The modern locomotive boiler is a barrel of tubes, with a steam space above. The heated gases from the fire are drawn by the exhaust draught through the tubes,

and the water in the boiler surrounds each one of the tubes, as well as the inner firebox. On their way through the tubes the heated gases contribute their heat to the surrounding water and raise steam. The outer surface of the inner firebox and the total outer surface of the whole of the tubes make up what is called the 'heating surface' of the engine. For example, the heating surface of the streamlined L.M.S.R. engine *Coronation*, which was the first engine to haul the 'Coronation Scot' train, is 3,663 square feet. Let us see if we can illustrate what this figure means.

Suppose that, instead of a multi-tubular boiler, the locomotive had a boiler consisting of a simple cylindrical barrel, say 6 feet in diameter, heated by means of hot gases all round it, excepting the two flat ends. In order that such a boiler might have a heating surface equal in area to that of the *Coronation* engine it would have to be just over 194 feet long, that is, very nearly thrice the length of a cricket pitch. This example illustrates very clearly how the ingenious device of the multi-tubular boiler has increased the area of the heating surface without increasing the overall dimensions of the boiler.

There is another feature of locomotive design which must be mentioned, namely, the process of 'superheating'. In superheating the steam is raised to a temperature higher than that at which it is generated in the boiler. It is generally known, for example, that in the household kettle water boils at a temperature of about 212° F. The steam that is thus formed is called 'saturated' steam, because, if it be cooled below that temperature, it immediately condenses into water. That is the explanation of the white cloud which forms about the kettle's spout.

In the same way, as was pointed out previously, when saturated steam begins to expand in the cylinders of the engine its temperature falls and condensation immediately ensues. This condensation may amount to as much as 20–30 per cent. of the total weight of the

steam used If, however, before the steam is allowed to enter the cylinders, its temperature is raised to, say, 650° or 750° F , it can cool considerably before saturation point is reached and condensation begins The consequence is that almost throughout the stroke of the piston the steam remains a gas or, as it is termed, 'dry' Not only so, but the effect of increasing the temperature of the steam by superheating is to increase its volume

Superheating thus confers two great advantages the loss of efficiency through condensation is practically avoided, and the increase in the volume of the steam enables larger cylinders to be used, and thereby the tractive power of the engine to be correspondingly increased In short, with superheating the same weight of steam can be made to do approximately 20 per cent more useful work than it could do if it were not superheated Nowadays no locomotive, except those used for shunting, is built without the provision of a superheater It may be noted that a smoke-box superheater was applied to locomotives on the old London and North Western Railway as far back as 1852

It was pointed out earlier that in Great Britain the fuel used on railways is almost invariably coal That is mainly because this country has abundant supplies of the best coal that the world produces In other countries where coal is difficult or impossible to obtain the most successful substitute for coal is oil Raising steam by means of oil-firing has certain advantages over coal For example, the fireman's task is greatly lightened In place of the arduous manual labour of shovelling the coal into the firebox we have the very simple operation of turning on the oil through a tap

Attempts have been made to use oil-fired locomotives in this country, but they have not been completely successful, at least from the economic point of view There are some technical difficulties, but they can be overcome The question, like so many of the other

problems we have discussed in previous chapters, is at the bottom mainly an economic one Is oil-firing more economical in the long run than coal-firing?

Attempts have also been made in recent years to use pulverized coal as fuel In this method the coal is ground by suitable machinery into particles as small as the particles of fine flour This pulverized fuel is fed automatically from the tender into the firebox Among the advantages claimed for the use of pulverized fuel are (1) it would lighten, as does the use of oil, the fireman's labour, and (2) it would reduce fuel costs by making it possible to use low-grade coal which cannot be burnt in the ordinary way in the locomotive firebox

One comparatively recent experimental development in the design of the locomotive which should be mentioned is the application of the steam turbine The ordinary locomotive engine, in which the pistons move to and fro in cylinders, is known as a 'reciprocating' engine In the steam turbine the steam impinges upon numerous blades set round a shaft, which causes the shaft to revolve, just as in a horizontal water-wheel the pressure and impulse of the water on the blades causes the wheel to rotate (Plate 12)

Now the outstanding advantage of the steam turbine is that it utilizes to a far greater extent than does the reciprocating steam engine the expansive properties of steam So to speak, it gets more work out of the steam before it lets it escape For this reason the locomotive engineer has naturally been itching to try whether in the steam locomotive the cylinders and reciprocating motion might not be supplanted by turbines

Experiments have been made with turbo-condensing engines in which the steam, after being used in the turbines, is led into a condensing plant The draught for the fire is supplied by a fan One type, the Ljungstrom, which comes from Sweden, was tried experimentally some years ago on the L M S R system Taking everything into account, however, including the costs

of building and of maintenance, the turbo-condensing engine has not proved to be markedly superior to the steam reciprocating engine

Thus far in this chapter we have dealt only with the steam locomotive But mention must be made of the heavy oil engine, known, from the name of its inventor, as the Diesel engine, which is finding increasing use on railways In the steam engine, as we have seen, the fuel (coal) is burnt in a separate firebox to raise steam, the steam enters the cylinders and by its expansion moves the pistons Thus the steam engine might be called an 'external combustion' engine

On the other hand, the Diesel engine, like the petrol engine used in the ordinary motor-car, is an 'internal combustion' engine The fuel (oil) is burnt actually within the cylinders of the engine, and the force of this combustion or explosion actuates the pistons A mixture of air and oil (in the form of fine spray) is drawn into the cylinder and compressed The oil is ignited by the high temperature produced through compression and not by any spark For this reason this type of engine is known as a 'compression-ignition' (or C I ) engine Notice that it differs from the ordinary petrol engine in not employing a magneto, sparking-plugs, or carburettor

The Diesel engine has another advantage over the petrol engine It is not so fastidious about the fuel it requires, but can use a wide range of oil as fuel Of all forms of engine used as prime movers the Diesel engine is the most efficient It converts approximately 75 per cent more heat units into work than an efficient steam engine. Railcars propelled by Diesel engines are used all over the world, and more than 3,000 are in regular operation Diesel traction was first applied in regular service in the British Isles on the County Donegal Railways, in 1931 Stream-lined Diesel cars are employed by the G W R for express services, such as that between Birmingham and Cardiff The Diesel locomotive is,

however, much more costly to build than an equivalent steam locomotive, and it is also relatively much heavier

One difficulty in applying the Diesel locomotive to railway traction is due to the fact that this type of engine is a constant-speed machine, so that some form of gearing or other means of transmitting its power to suit the varying speed conditions is necessary Electrical and mechanical systems of transmission have proved most satisfactory so far There is a Diesel-electric locomotive in which the virtues of the Diesel engine and the advantages of electric traction are combined But we must leave a description of this development until we come to deal with the subject of electric traction

CHAPTER VII

# BUILDING AND REPAIRING LOCOMOTIVES

In the preceding chapter we have considered some of the leading features that affect the design of the locomotive. It is clear that, before the design can be properly settled, there are very many preliminary points to be taken into account. For example, the designer must know what type of work the engine will be called upon to do, under what conditions it will have to work, and so forth. When these preliminary considerations have been duly weighed, then, and only then, is it possible to settle definitely the design of the particular type of locomotive required. When the broad principles of design have been determined, the draughtsmen prepare the working drawings, in which all the principles of the design are worked out in the fullest detail.

It is thus in the drawing-office that the locomotive engine may be said to start into being. It is first born on paper. The designing staff spend many weeks, perhaps months, in preparing the working drawings, and they also set out in full detail particulars of the materials to be used and of the methods of construction to be followed. It is from copies of these drawings that orders are sent out for the necessary materials to be obtained from the contractors and manufacturers.

In modern practice the various separate parts of the locomotive—e.g. the boiler, the motion parts, the wheels, &c.—are manufactured in separate shops, each specially equipped for the work it has to do. These shops are arranged in such an order as to save, as far as possible, waste labour in handling and transporting the materials. Many of the component parts are, of course, purchased from outside manufacturers. The several parts eventually reach one large shop, an erecting or assembly shop, in which the parts can be fitted together

to make the complete locomotive Three stages in the erecting of a locomotive are shown in Plate 13

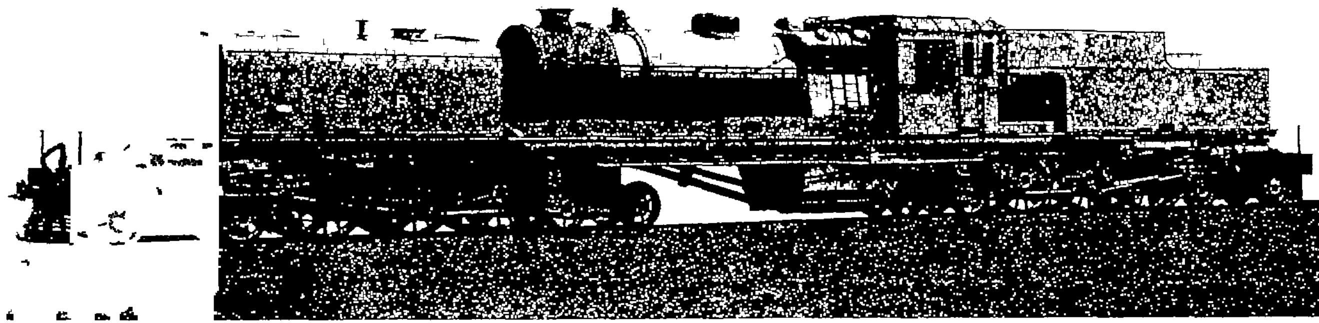
The first step is to set up the frames which are to be inside the wheels and to extend the whole length of the locomotive These frames are made of steel plates, rolled to the thickness required—from 1 to 1¼ inches Usually the plates come into the erecting shop slotted and straightened and having, as far as possible, all the necessary holes drilled in them and the sharp corners taken off These plates are placed upright, carefully adjusted to the correct positions, and then are bolted firmly together, so as to form a rigid frame This frame, it will be remembered, is the undercarriage of the locomotive, which is to transmit the tractive power through the drawbar to the train

Next, an overhead crane lowers the cylinders into position The cylinders are carefully adjusted so as to be exactly parallel to the frames and to each other They are then firmly secured in this position, and the motion or slide bars, along which the crossheads of the piston slide to and fro, are fitted

The boiler with its various brass fittings has come meanwhile from the boiler shop to the erecting shop By means of a crane it is now lowered on to the undercarriage and bolted securely to it The firebox end is supported in such a way as to allow for the expansion of the barrel when it is heated Thus the boiler is free to expand lengthwise

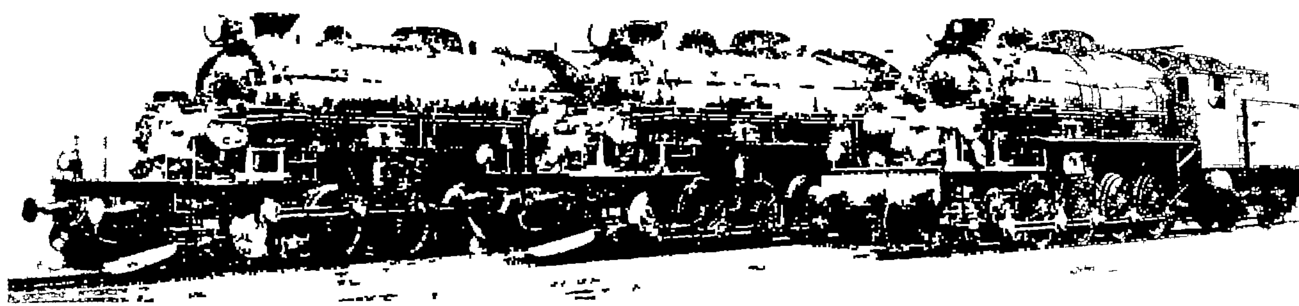
When the boiler is securely fixed in its proper position, the exposed portions are 'lagged', that is to say, they are covered with a non-conducting material, in order to reduce to a minimum loss of heat by radiation Felt, preparations of asbestos, or of a material known as silicate cotton are most often used for lagging The whole of the boiler is now protected with a kind of overcoat, consisting of steel sheets held in position by strong steel bands

After all these operations connected with the boiler have been carried out, the smoke-box, the driver's cab,



Beyer-Garratt locomotive built for Sudan Railways

*By courtesy of Beyer Peacock & Co Ltd*



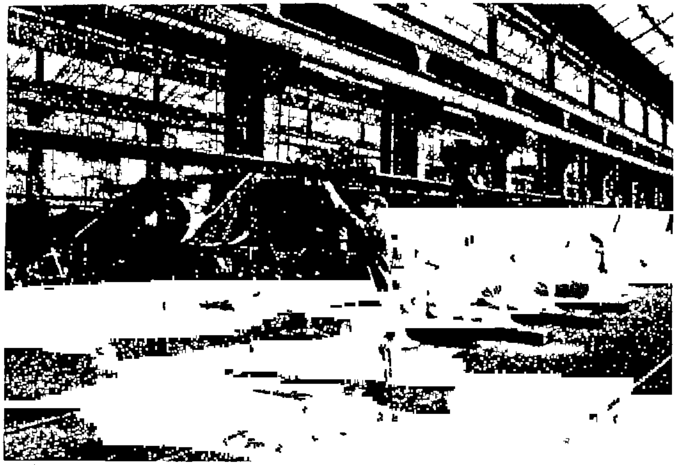
Ljungstrom non-condensing turbine locomotives on the Swedish Railways

*By courtesy of the Railway Gazette*

PLATE 13

## Building a modern locomotive (the 'Royal Scot')

(The completed locomotive is shown in Plate 21)



Setting up the main frames

Boiler in position on frames but without its outer lagging Cylinders fitted

Boiler lagged cab in position and engine being 'wheeled

the axle-boxes, and numerous other details are fitted and made secure

The engine is now ready to receive its wheels, which have been brought to the erecting shop from the wheel shop Overhead cranes lift the locomotive clear of the standard-gauge track, which runs through the erecting shop, the wheels are rolled underneath into the correct positions and the engine is lowered on to them

The next stage is to fit the motion parts or, as they are usually called, 'the motion', after which comes the setting of the valves The springs are then fitted and fastened, the buffer beam is attached and the coupling-rods are put on Finally, when all the other minor details, such as the brake gear and the various feed pipes, have been completed, the engine is ready to leave the erection shop

When a new locomotive or one that has been overhauled leaves the erecting shop, the tender is attached, and engine and tender now pass to the paint shop The requisite number of coats of paint are applied and the whole is allowed to dry at a uniform temperature Immediately after the locomotive leaves the paint shop it is 'put into steam', and the various gears, including the brake gear and the reversing gear, are carefully adjusted The engine is next given a short run of about twenty miles, and in the light of the knowledge gained during this run final adjustments are made

The engine is sent to its home station—i e to the engine shed which is to be its future home—where it is gradually broken in to do the class of work for which it has been designed

The next thing to do is thoroughly to test the locomotive Usually a separate department of the railway sees to this business If the engine is an example of a new type, full particulars are needed of its performance under ordinary working conditions For this purpose a temporary cab, known as the 'indicating cab', is fixed at the front of the engine It will accommodate at least two

test or experimental engineers, as well as the apparatus by which what is called the 'indicated horse-power' of the engine is measured

Use is also made of a special car equipped with appropriate apparatus and known as the 'dynamometer car' (Plate 14) This car is placed between the engine and the train In it there are an instrument called a dynamometer and other apparatus which give valuable information The instruments show how the drawbar pull between the engine and the train varies from time to time throughout a particular run They measure also the total work done by the engine during the run These data are compared very carefully with information, which is obtained at the same time, showing the amount of coal and water used Thus a measure of the efficiency of the engine can be determined

It is only by such thoroughgoing and exhaustive tests that the true value of the engine is revealed After these tests any necessary slight alterations in the design that seem to be desirable are carried out The running tests are then again applied and more adjustments are made, and so the game of test and adjustment, test and adjustment goes on, until the locomotive engineer is satisfied with the result

It is not, however, only with the building of new engines that the locomotive works of a great main-line railway system are concerned An equally important function of the works is to keep in good going order the locomotives that have already been built These locomotives have to undergo constant examination and, where necessary, repair, in the interests not only of safety but of economy

Different railway systems may differ slightly in their plans for ensuring the systematic and thorough repair of their locomotives In general it may be said that the first duty is to obtain systematically and regularly exact knowledge of the condition of each locomotive in service For example, on the L M S R this duty is

assigned to what is called a central 'shopping' bureau For each class of engine a period is fixed that runs from the time of the last heavy repair (or the time when the engine left the shop new) to the time when the engine is to be considered for the next overhaul This period is called the 'shopping period' For the larger passenger engines it is twelve months and for the freight engines it varies from eighteen to thirty months

Note, however, that it is not a rigidly enforced rule that at the end of its specified 'shopping period' an engine must come into the shop for general overhaul, whatever may be its condition After all, it may not really need a complete overhaul Accordingly, special forms are issued to the engine sheds, known usually as the 'running-sheds', which, as was indicated previously, are the daily homes or stables of the engines On these forms the condition of each engine is described in detail two months before it is due to come into the shops for repair

For example, in the case of a passenger engine, ten months from the time when it last left the shops, either as a new engine or after heavy repairs, a careful examination must be made of its condition A report of the state of the engine is submitted, to enable the shopping bureau to decide whether or not the engine can be safely relied upon to continue in service after the set period of twelve months The engine in question is then either definitely booked for shopping, or else allowed to continue in service for a further prescribed period

If it has been given this further lease of running life, again two months before the conclusion of this further period the same procedure is followed It often happens that at the expiration of such further period careful examination of the locomotive shows that it is still fit to continue working, and, if so, it is given yet another period of service before undergoing complete overhaul

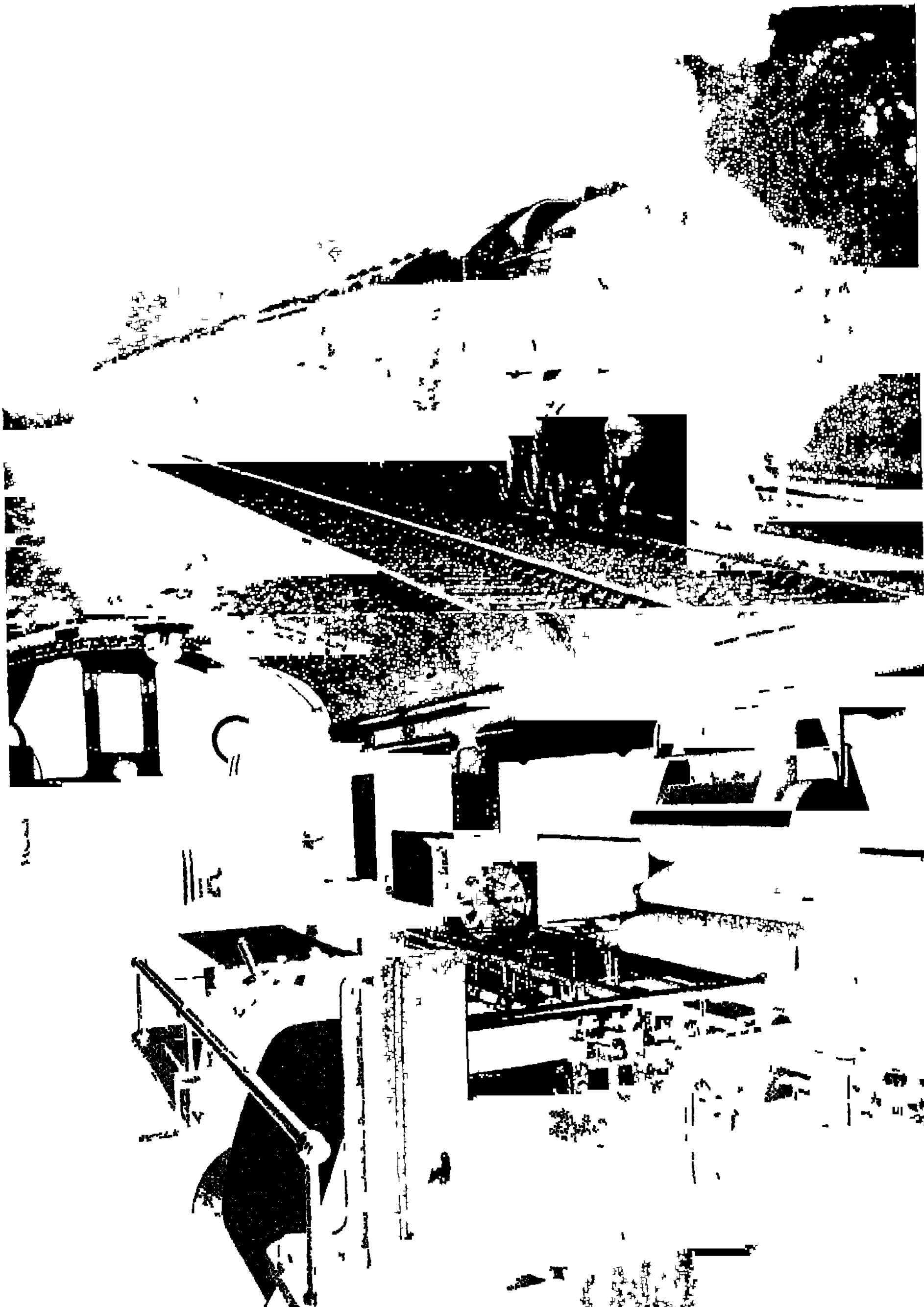
It will be clear that such a system of periodical inspection enables the last available mile to be got out of the

engine without increasing the risk of break-down It is really, one might say, applying to the locomotive the principles of preventive medicine It is in this way that the railways keep a regular and careful watch over the individual health and fitness of the multitude of locomotives running over their systems

It should be said here that in the foregoing paragraphs we were dealing with what may be called the major repairs of the locomotive Minor day-to-day repairs and readjustments are usually effected at the running-sheds to which the engines return, as far as possible, each day, each engine having its assigned running-shed This daily examination at the running-sheds is directed mainly to making sure that the engine is fit to perform its tasks for the next day, whereas the periodic examination two months before the 'proposal for shopping' is to enable the authorities to decide whether the engine should now be completely overhauled to render it fit for another long period of service

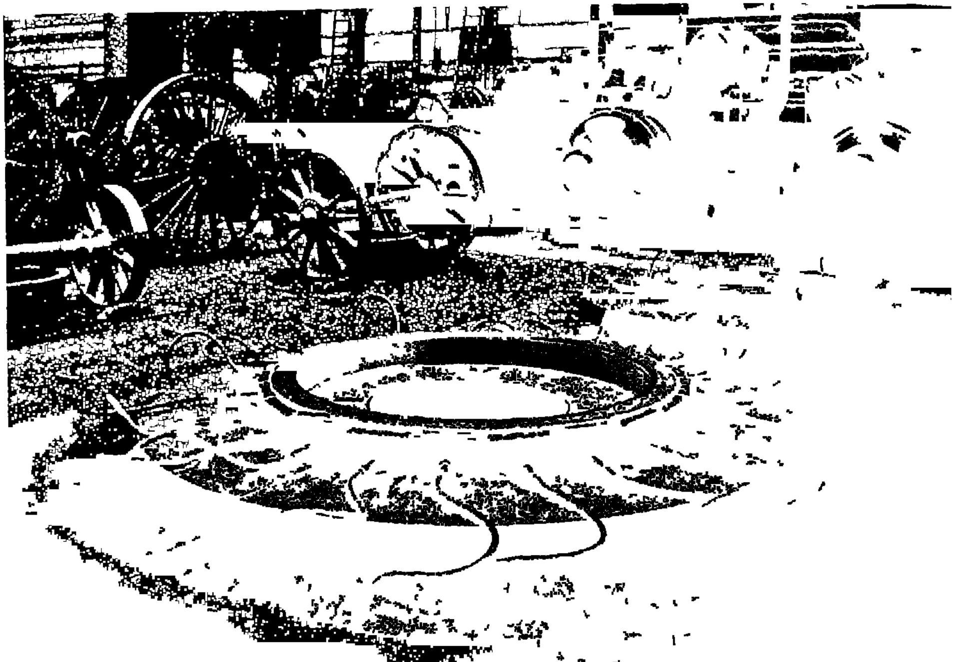
It is a most interesting experience to pass through the erecting shop of a great locomotive works and to notice the way in which all the operations are carefully planned beforehand As the locomotive to be overhauled enters the shop it is first taken completely to pieces All the parts are carefully examined by inspectors expert in this particular work They indicate which parts are to be replaced entirely by new ones because they are worn out, and which are to be merely repaired

The boiler goes to the boiler shop for repair, the wheels to the wheel shop, and so forth The work is done in progressive stages, the engine itself entering the shop at one end and leaving it completely overhauled at the other The road or path along which the engine moves progressively through the shop is furnished with a rail track of standard gauge and is known as a 'belt' This method of erecting or repairing is known as the progressive method, since the unit involved—in this case the locomotive—progresses steadily forward from



By courtesy of L.M.S R

*Above* The Irish Mail with indicating cab
*Below* Interior of railway dynamometer car



*Above* Shrinking tyres on wheel centres
*Below* Fitting the completed roof to a passenger coach

*By courtesy of L.M S R.*

one stage to another At each stage a group of workmen perform the jobs allotted for that stage When the locomotive reaches the end of the belt the task is completed

It may be of interest to notice some of the individual operations which are involved in the construction of a locomotive The wheels, like those of the rolling-stock, have steel tyres The wheel without its tyre is called a wheel centre After the wheel centres have been fitted to the axle the next operation is to affix the tyres The tyre is first bored out so that its inside diameter is a fraction of an inch smaller than the outside diameter of the wheel centre In this condition, of course, the wheel centre 'won't go' The tyre is next placed flat on the the ground and heated by means of a ring of gas jets to a temperature of about 250° F This heating, of course, causes the tyre to expand, and the wheel centre is then lowered into it by suitable tackle The gas jets are turned off, and as the tyre cools it contracts and thus becomes a tight fit on the wheel centre (Plate 15)

The boilers are tested by steam and also under hydraulic pressure, in order to ensure that they can withstand the maximum steam pressure at which they will be called upon to work It is the usual practice to test the boiler under hydraulic pressure at 50 per cent above the pressure at which normally it will have to work, and then to make a steam test at 10 lb above the working pressure

In the examination of rods and motion parts a very simple method is adopted for the discovery of flaws or minute cracks Since the parts being examined have been removed from engines that have newly arrived at the shop from service, they carry, of course, a thin film of oil By tapping the rod or part with a light hammer vibration is set up, which causes the oil to exude from any tiny fracture that may exist After the first tapping the part affected is wiped dry and again tapped, when even a very minute or 'hair' crack will be revealed by the appearance of further oil on the surface

Although this method is so simple, nevertheless in practice it is found to be so effective that very rarely, if ever, does even the most minute defect escape detection

In the inspection of wheels a slight modification of this method is adopted The wheels are pushed along a rail track on a small platform, from which they are let fall on to a ground track about 10 inches below The jolt as the wheel drops from the higher to the lower level

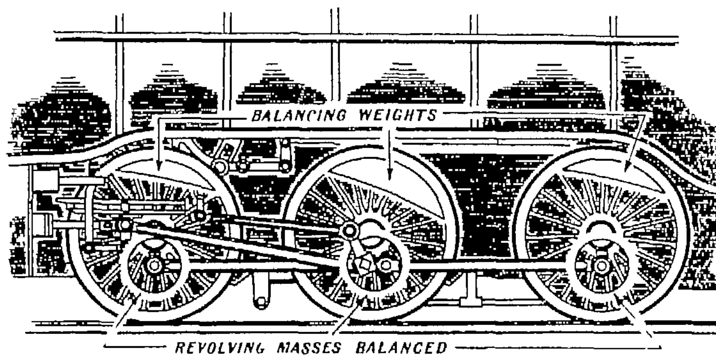



FIG 15

sets up vibrations throughout the whole wheel, which have the same effect as the hammering that has just been described, that is to say, the jolts bring out any hidden oil to indicate the location of a fracture

One of the problems of locomotive design is what is called 'balancing' The swinging round of the heavy cranks and of other motion parts creates powerful disturbances If these disturbances were uncontrolled they would make the engine oscillate considerably and even dangerously In order to reduce these disturbances as far as possible, the cranks and other moving parts are counterbalanced by crescent-shaped masses of metal set in, or near to, the rims of the coupled wheels, so that the wheels as a whole may be more or less balanced as they revolve

For this purpose special wheel-balancing machines

are employed On these machines the driving-wheels, with their cranks and eccentrics, are spun round at high speeds, and any want of balance is thereby made manifest Crescent-shaped steel plates are fastened on each side of the spokes of the wheel centres and thus form cavities According to the indications given by the balancing machine, these cavities are filled with lead to the exact weight required to restore the balance The method is a delicate one and the balance can be adjusted to a fine degree of accuracy

## CHAPTER VIII

# THE ROLLING-STOCK

JUST as there is a need on a big railway system for many and various types of locomotives, so many and varied types of carriages and wagons are needed—more numerous and various, indeed, than the types of locomotives. Let us look in this chapter at some of the problems that have to be solved in designing the carriages and wagons in which passengers and goods are transported. For convenience we will call these vehicles the 'rolling-stock', though, of course, strictly speaking, that term should include the locomotives.

The designer of the rolling-stock, like the designer of the locomotive, must, of course, bear in mind the dimensional limits imposed by the track and construction gauges. His designs must also, of course, be governed by the particular purposes the several vehicles are to fulfil—the carriages to carry and, in some cases, to feed and 'sleep' passengers, the wagons to carry almost every variety of goods.

Obviously the vehicles must be strongly built, not only in order that they may sustain the loads they will be called upon to carry, but also that they may have a long life and low costs of maintenance. On the other hand, every pound weight by which they are heavier than they need be means so much additional weight—and, be it noted, unremunerative weight—to be hauled by the locomotive, with a consequent increase of coal consumption. The ideal railway carriage or railway wagon would be a vehicle extremely light, extremely strong, and, at the same time, extremely roomy, that is to say, having maximum accommodation for the paying load—the fare-paying passengers or the freight-paying goods.

There are three leading considerations to be taken into account in the designing of carriages and wagons

First, cheapness of construction, second, the weight of the empty vehicle—the 'tare' weight—in proportion to its capacity, and third, what may be called the versatility of the vehicle, that is to say, its suitability for carrying as many kinds of goods as possible This last consideration is perhaps the most important of the three, because the greater the versatility of the vehicle the greater is the chance of its being loaded in both directions, a practice which, of course, reduces the total number of vehicles required

In the earliest days of railways the ideas of passenger coaches were naturally derived from the experience of stage-coaches Not only the name but the design followed that of the stage-coach, the first type of railway coach being merely a road vehicle adapted to run on rails 'Dickey' seats were provided for the servants of the inside first-class passengers There were at first only two classes of passengers, the second-class having to be content with uncovered wagons with primitive seats laid across, and in these crude wagons the passengers undertook all-night journeys In 1862 the Belfast and Northern Counties Railway provided third-class carriages on all its trains, and in 1872 the old Midland Railway Company also adopted this practice and, a few years later, abolished the second-class

Consider now the design of passenger coaches, especially for express services, in these days Besides providing for the seating accommodation, the designer has to allow for a vast number of additional comforts, e g reduced vibration, lessened noise, increased safety communication, warming, lighting, and ventilation, corridors and lavatory accommodation, facilities for taking refreshments and meals on board, and even sleeping accommodation. Moreover, modern standards require comfortable and even luxurious upholstery, not to mention artistic decorations

It must be noted in this connexion that to provide all these additional comforts it has been necessary to

increase the weight of the coaching stock per passenger conveyed Moreover, to lengthen the life of the stock and to reduce maintenance costs, more solid methods of construction have been introduced, and, in particular, steel has been substituted for wood wherever practicable These measures in their turn have also increased the weight of the train without adding to the seating accommodation It is largely these developments that have made it necessary in recent years to increase continuously the power of express locomotives

We saw that it was necessary, largely on economic grounds, to have several distinct types of locomotive In the same way it is necessary to have several varied types of coaches For local non-express trains there is the non-corridor stock, for express trains the corridor stock In addition there are brake-coaches, lounge-cars, saloon-coaches, dining-cars, buffet-cars, kitchen-cars, sleeping-cars, and coaches fitted for electrical traction Most people who have travelled by rail will be familiar with the main features of the designs of these various types Here let us glance at certain features of coach design that the ordinary passenger may overlook

Whatever may be the type of the coach nowadays, it consists essentially of a steel frame mounted on wheels and carrying above it the enclosed body The enclosed body may be of steel or wood, or a combination of both The earliest coaches were carried on four wheels As longer coaches were built, in order to provide increased seating accommodation, the number of wheels was increased to six

At a still later stage the principle of bogie suspension, which had already been adopted in connexion with the leading wheels of the locomotive, was applied to the coaching stock A coach has normally two bogies The bogie is a four-wheeled or sometimes a six-wheeled truck, pivoted under the frame of the coach and having a limited amount of side play The bogie frame is thus free to swing to some extent independently of the frame

of the coach, and it is this freedom of the bogie which gives flexibility to the carriage as a whole and makes it possible for the curves in the road to be traversed at high speeds. To-day the use of the bogie for all kinds of passenger rolling-stock is practically universal.

Besides enabling the train to round curves smoothly and easily at high speed, the bogies confer another benefit. They absorb a large proportion of the shocks that the train receives in passing over switches, crossings, joints, and other inequalities in the track. In this way the bogies contribute a good deal to smooth and steady running.

The normal type of coach bogie is carried on four wheels, the two bogies thus providing eight wheels to support the coach. Sometimes, however, six-wheeled bogies, making a twelve-wheeled coach, are used, as, for example, in the latest type of sleeping-car on the L.M.S.R. This heavier type of bogie has been adopted in this case, in part because of the greater weight of the sleeping-car, and in part to serve as a larger and more effective shock-absorber than the ordinary four-wheeled bogie for the inequalities of the track. This last consideration is obviously an important factor in a sleeping-car.

There is a point in connexion with the weight of this sleeping-car which affords another illustration of the economic questions that so often lie behind choice of design—as we have seen several times previously. The normal twelve-wheeled sleeping-car of the L.M.S.R. weighs 42 tons (as compared with the 27 or 28 tons weight of the standard corridor coach) and it accommodates twelve passengers. That is to say, the coach weight per passenger carried is no less than 3½ tons. It is mainly for this reason, and not because of the cost of sheets, pillows, and mattresses, that passengers on the sleeping-car have to pay a supplementary charge per berth in addition to the first-class fare. It may be interesting to note here that sleeping-carriages were first

introduced in Britain on the west and east coast routes to Scotland in 1873

We may now consider some features of the braking, lighting, and heating systems now in use As we shall see, these, too, have an important bearing on the economic aspects of train running

Locomotive brakes are of three principal types, namely, hand, steam, and continuous automatic The hand and steam brakes, as a rule, are for use on the locomotive itself In passenger trains a continuous brake-pipe runs from end to end of the train, from the engine to the last carriage, and enables the driver to apply the brakes on every pair of wheels throughout the train Under the carriages this brake-pipe consists of a steel tube The connexion from coach to coach is made by means of a rubber pipe, strengthened by stout wire or by some other form of armour By an Act of Parliament of 1889, continuous brakes were made compulsory for British passenger stock

On British railways two diametrically opposed types of brake have been generally employed on passenger trains for many years past—the 'Westinghouse' brake and the 'automatic-vacuum' brake In the former the force that applies the brake-blocks to the wheels is derived from compressed air, in the latter the brake-blocks are applied by destroying a vacuum in the brake cylinder—in other words, by letting in air It is the engine that works the compressor in one case and exhausts the vacuum in the other As to the power of the brakes, it may be stated, by way of illustration, that a train of 500 tons behind the tender of a modern express locomotive, running at a speed of 60 miles per hour on the level, can usually be pulled up in a distance of about 360 yards

In the development of railways the lighting of the carriages has passed through three stages oil, oil-gas, and electricity To-day electric lighting is almost universally employed The electric current required is

generated by a dynamo, which is fastened to the under-carriage and is driven, by means of a belt, off one of the axles of the coach The electricity thus generated is stored in accumulators which are also carried under the coach Thus an ample source of current is available even when the coach is standing and the dynamo not working

Until well into the present century the only means adopted to heat the passenger compartments was the use of flat, oblong tin vessels called 'foot-warmers' They were placed on the floors of the compartments, and in the early years of their use were filled with hot water at numerous depots stationed along the main lines At a later period 'patent' foot-warmers were introduced, in which crystallized acetate of soda replaced the water In the vessels so filled the heat, before it had quite disappeared, could be restored by merely shaking the receptacle Moreover, the heat was retained nearly three times as long as in the ordinary hot-water tins

Nowadays the passenger carriages are heated by steam, which is supplied from the locomotive boiler, at a suitably reduced pressure, through a pipe which runs throughout the length of the train, the connexion from coach to coach being made by means of a flexible hose-pipe The heating elements of each compartment are placed under the seats of the carriages and communicate with the main steam-pipe, the amount of steam admitted, which regulates the degree of heating, being under the passengers' control In the winter months this steam supply is used also to heat the water in the lavatories for washing purposes

One important point should be noticed in connexion with the methods, just described, of braking, lighting, and heating the train they all add to the work required from the locomotive The braking calls for steam, either to work the air-compressor or to exhaust the vacuum The heating is a direct drain upon the steam supply, and the lighting demands more work from the loco-

motive because of the increased friction to be overcome in driving the dynamos from the axles of the carriages And since these things demand more power from the locomotive, they demand more fuel and they add to the running costs

We may now take into account certain factors that arise in considering the design of wagons for the conveyance of goods The goods that are to be carried vary far more widely in dimensions and physical characteristics than do the passengers, and consequently there must be more numerous and more varied types of wagons than of coaches Generally speaking, in this country there are three main types in general use the covered wagon or, as it is often called, the 'box' wagon, the ordinary open wagon, and the flat wagon Each of these three types has many varieties For example, the box wagons include refrigerator wagons for keeping such goods as foodstuffs at a low temperature, insulated vans for use where it is desired to maintain an even temperature, steam-heated wagons for such freight as bananas which, in winter time, require a high temperature during transit to prevent the ripening process from being arrested, horse-boxes and cattle trucks

The differences between the varieties of open wagon are chiefly in regard to their capacity and the devices adopted for the discharge of their contents For example, the contents may be discharged by side door, by end door, or through the floor by hopper There are also, of course, wagons specially designed for carrying particular commodities, such as chemical wagons, oil wagons, glass-lined milk wagons, and gunpowder wagons

Among the many varieties of flat wagons we may note those which are intended for the carriage of lengthy loads, such as steel rails and timber These wagons are provided with blocks of wood or iron, called 'bolsters', on which the load actually rests For the accommodation of loads of unusually large bulk 'well' wagons are provided. These are flat wagons which have their cen-

tral portions sunk, so as to form a well, the load being placed in this well so that it may not foul the bridges and tunnels encountered *en route*

A recent development is the introduction, or rather, the reintroduction, of the 'container' wagons These are flat wagons which carry detachable boxes, or containers, that can be lifted bodily off the wagons on to road lorries The goods in these containers are thus conveyed 'from door to door' The great advantage of the container is that it eliminates the unloading of the freight, item by item, from the lorry to the train at the beginning of the railway journey, and from the train to the lorry at the end of it In this way a great deal of handling is saved and the risk of breakage and of damage is consequently reduced

In Great Britain it is almost the universal practice to couple the wagons together loosely, by means of a chain of three stout links, in order that the shunting staff in the goods yards can couple and uncouple the wagons easily with the help of a pole, without having to go between the vehicles Furthermore, this loose coupling enables the engine-driver to stop his freight train with all the couplings slack, so that, when he starts again, the load goes on to the engine gradually as the couplings tighten in turn from end to end of the train This gradual coming on of the load has one great advantage, that it enables freight engines of moderate power to be used A freight train that was coupled as rigidly as is the normal passenger train would require an engine of increased power to enable it to start

In North America automatic couplings only are used In this system two wagons, on being brought together, couple themselves automatically and rigidly, not loosely, provided that the couplings are set in the right position to engage each other The difficulty referred to above of starting a heavy, rigidly coupled freight train is overcome in many cases by fitting the locomotive with a supplementary engine, called a 'booster', which helps

to start the train and is cut out of action when the train is running

Many advantages are claimed for the use of automatic couplers Not only do they reduce considerably the risk of injury to the men employed in shunting operations, but they economize time in the goods or marshalling yards Moreover, automatic couplings being usually of greater strength than the loose chain, the risk of 'breakaways' due to broken couplings is less

There are two factors which have so far operated against the adoption of automatic coupling on British railways In the first place, the wagons used in this country are of smaller capacity than those used in other countries To adopt automatic couplers would add a disproportionate amount to the tare weight of the British wagon Moreover, a very large proportion of the wagons of British railways are privately owned, and to substitute automatic couplings for the loose couplings would be to put a heavy financial burden on the owners of these wagons

With regard to braking, the ordinary British freight train has each and all of its wagons equipped with hand-brakes In the more modern type of wagons the brakes can be applied from either side Notice, however, that these hand-brakes cannot be applied when the train is in motion on the journey When the train is running the only brake power that is available, therefore, is that which is supplied by the brakes on the engine and tender at the front, and by the screw hand-brake on the guard's brake-van at the rear

Suppose, therefore, we consider the case of an average coal train having a total weight of, say, 1,200 tons The aggregate brake-power provided by an engine and tender weighing together from 110 to 120 tons and by a brake-van weighing 20 tons amounts at the most to 140 tons weight. Such a braking weight, in proportion to the total moving weight of the whole train, is only moderate in its retarding power It is for this reason that, if the

average British freight train is to be operated safely, either it must be run at comparatively low speeds or else it must be limited in weight for high speeds The general tendency has been to adopt the second course, the average formation of a British freight train being not much more than thirty-five wagons of small capacity

Still more recently a tendency has grown up to increase the speed of freight trains Consequently a growing number of them are fitted with 'through brakes' of the vacuum type These through brakes apply either to the whole train from engine to brake-van or, at any rate, to the front part of the train By thus increasing the braking power some of these fast goods trains are enabled to travel with safety at speeds approaching those of passenger trains In Britain many goods trains, fitted with continuous brakes, are booked over long distances at speeds exceeding 40 miles per hour

CHAPTER IX

# BUILDING AND REPAIRING CARRIAGES AND WAGONS

WE have seen in the previous chapter that in providing adequate rolling-stock for a great railway system the types of stock must be many and various, so that, for the conveyance of a particular class of passenger or a particular kind of freight, the type of rolling-stock that is most economically appropriate may be used

Just as in the case of the locomotive, so in the case of the rolling-stock, the first step, after the broad principles of any particular design have been settled, is to prepare the drawings These drawings give full details of how the various component parts are to be constructed and the complete unit to be assembled In Great Britain the 'Big Four' railway companies build a great deal of their own rolling-stock, though they also purchase a considerable amount from outside manufacturers In order to give a concrete example, we will consider certain features of the methods followed by the L M S R

Since the amalgamation in 1921 which, it was pointed out in the first chapter, brought this company into being, a new building has been erected at Derby to accommodate the drawing-office staff under one roof This central drawing-office designs all new rolling-stock that is to be built at any of the company's works The orders for the building of new stock are issued from the headquarters of the company, and the central drawing-office supplies not only the necessary working drawings but also the specifications of the materials to be used

The building of new rolling-stock is restricted to three main centres, at Derby, Earlstown, and Wolverton. Other works and shops distributed about the system deal with heavy repairs, and also with what are called 'running repairs', i e the repair of small defects

which develop on vehicles in traffic but do not need the attention of the main works

In the past carriages were built as houses are built to-day, by assembling them on one spot This meant that a number of workpeople belonging to various crafts —engineers, electricians, carpenters, joiners, upholsterers, &c —had to congregate together in order to carry out their respective jobs on the vehicles Under the modern system of construction—a system which is called 'unit assembly'—the construction of the parts is divided into several separate units, such as quarters, ends, roofs, and doors, and, as in the case of the locomotive, these several parts are brought together at a suitable stage and the assembly of the complete unit is effected on the progressive system (see Plate 15)

When an order is received for the construction of new rolling-stock, a schedule is prepared which prescribes the actual number of working days allowed for the construction of a vehicle from the date the drawings and specifications are issued to the head drawing office to the date when the vehicle passes into traffic This schedule also prescribes the number of days allowed to the stores department to obtain the necessary raw material, and each shop manufacturing some separate part is allowed a definite number of days for the execution of its portion of the work

The building of a new vehicle is carried out in a series of stages Each stage is allotted a definite amount of work, which must be completed according to a prearranged time-table Under this system of unit assembly only about six hours are required from the time the carriage under-frame is brought into the body construction shop to the time when the roof is finally affixed

The progressive system is also applied to the repair of the rolling-stock Here again there is prescribed for the rolling-stock, as we saw there was for the locomotive, a definite period of overhaul On the L M S R a system has been adopted which ensures that all the carriage

stock belonging to the company passes through one or another of the main works for intermediate repairs every eighteen months and for complete overhaul every six years Each time a vehicle comes into a repair shop on the eighteen months cycle the outside is washed and varnished, the inside furnishing is repaired where necessary, and the running gear is overhauled Every six years the coaches undergo a more thorough general repair, and their outsides are repainted and varnished

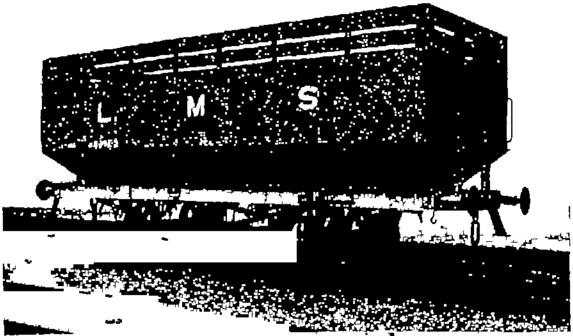
A similar system is adopted for the periodical overhaul of the wagon stock When a wagon undergoes general repairs a plate is affixed to it recording the date of this general repair In accordance with the scheme of overhaul, the wagon must be sent into the repair depot at the expiration of seven years from that date

It will be obvious from what has been said already that the care and upkeep of the rolling-stock is vitally necessary for two main considerations, safety and economy No one can go through the carriage and wagon works of a big railway company without realizing what an enormous amount of care is bestowed upon the maintenance in first-class condition of the rolling-stock

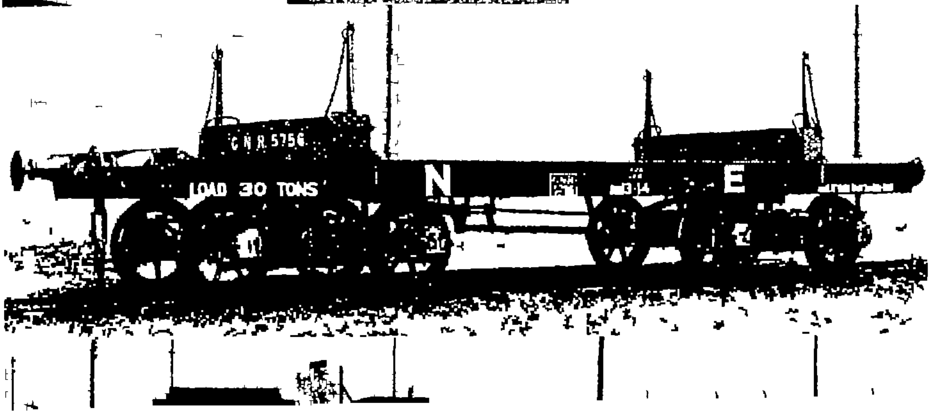
It is very interesting to note, by the way, how the operations of the shops are affected by happenings in the outside world For example, the Grand National Steeplechase is run at Aintree, near Liverpool, in March each year There is a great demand for first-class carriage stock for the special trains that are run in connexion with that event The consequence is that, for some weeks in advance of the race, priority is given in the L M S R carriage shops to repair work on first-class carriage stock On the other hand, as Bank Holidays approach or the summer excursion season comes near, work in the shops is concentrated on the repair and reconditioning of the third-class carriage stock

Why does a railway company manufacture its locomotives and rolling-stock instead of buying them? The question is often asked whether it would not be better,

20-ton coke wagon



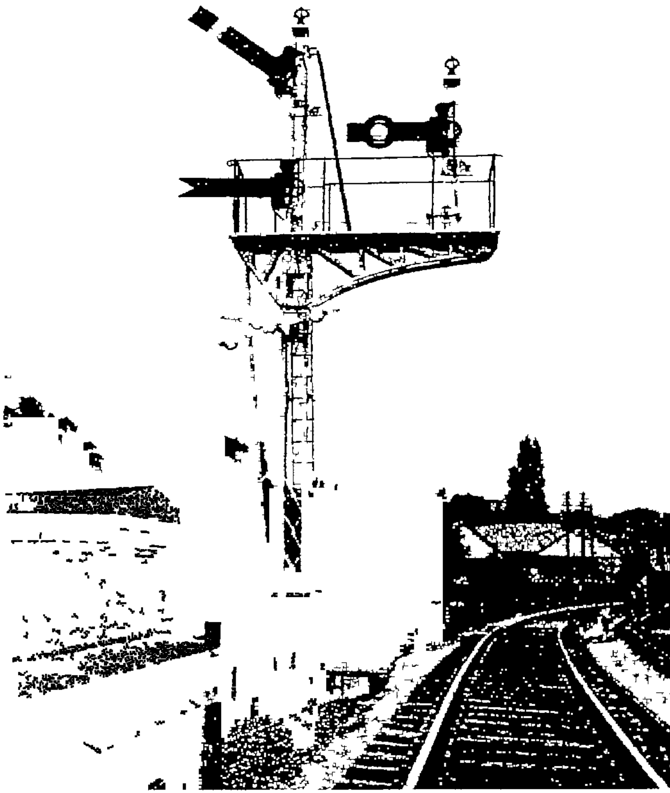

30-ton bogie flat (bolster) wagon



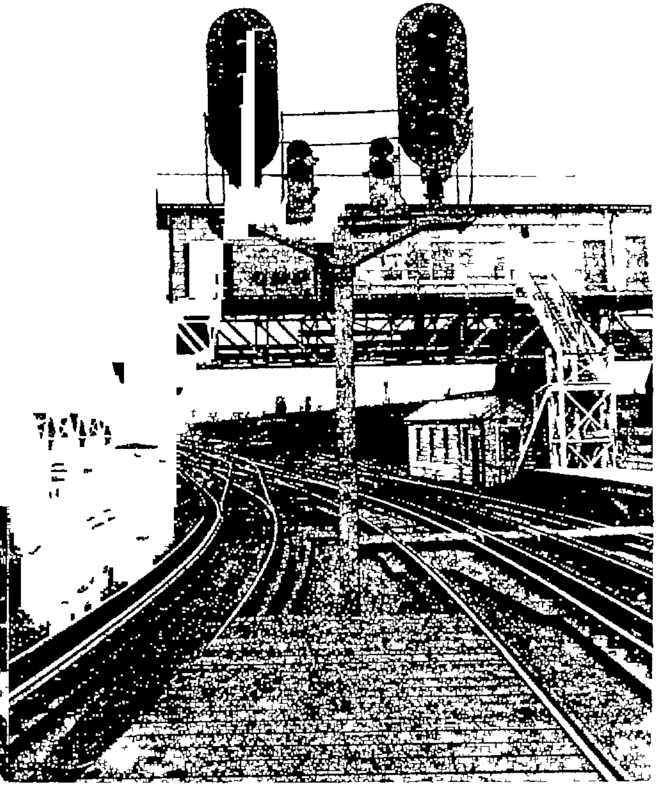

65-ton trolley (well) wagon


Bulk grain wagon

*By courtesy of L M S and L N E Railways*



Starting and distant upper quadrant signals



Four-aspect colour light signals at Charing Cross

*By courtesy of Southern Railway*

on economic grounds, for the railway company to confine itself strictly to railway business and to leave these manufacturing activities to others whose business is manufacturing

To this objection it may be answered, first, that British railway companies do, in fact, purchase a good many of their locomotives and much of their rolling-stock from outside manufacturers Secondly, as we have seen, the railway companies must keep their engines and rolling-stock in good condition This requires, of course, the provision, on a large scale, of workshops, machinery, and other equipment, which, to a very great degree, are suitable as well for the manufacture as for the repair of the stock That being so, it is held that there is ample justification for the railway companies to use this equipment for manufacturing purposes

Mr W V Wood, a vice-president of the L M S R company, claims that on balance the policy of manufacture by the railway companies has been truly economical 'It is necessary,' he says, 'as regards repairs, and the equipment provided for this purpose, if used to its full capacity in the periods of the year when repair work is slack, can, with the greater spread-over of standing charges, be used with economy in construction work With the formation of the large groups in Great Britain, that economy has been increased by the resultant ability to concentrate a particular class of work for the whole of one group in one existing shop, and another class in another shop, so that there is a continuous output of standardized parts and assembly of units '

There is one other subject in connexion with freight rolling-stock to which perhaps we should now draw attention, and that is the size or capacity of the wagons The average capacity of railway wagons is governed very largely by the social, industrial, and geographical conditions of the country in which they are to be used Great Britain is a densely populated country, in which the cities and towns are not only numerous but comparatively

near to each other The consequence is that even the longest freight train journeys are short when compared with those in some other countries Not only so, but a large proportion of the freight transported in this country consists of merchandise and manufactured articles which are carried, as a rule, in small consignments For example, in 1937 the staff of the L M S R loaded and unloaded no fewer than 110,841,950 consignments, the average weight of these consignments being in the neighbourhood of a quarter of a ton

These conditions differ widely from those that prevail, for example, in America There the greater part of the freight transported consists of raw materials and of foodstuffs, and is usually carried in large consignments over very great distances It is therefore rather beside the point to compare the capacity of wagons in this country with the capacity of wagons in countries like America In Great Britain, for the reasons that have been given, small consignments are the rule, and that is why the wagons of this country are in general of smaller capacity in proportion to the track gauge than those of any other country in the world

Nevertheless, it is recognized by British railway companies that to increase the average capacity of the wagons that are used would result in certain economic advantages Obviously, however small may be the load of a freight train, it is still necessary to provide engine, fuel, driver, fireman, guard, and brake-van, and thus these 'overhead' costs remain constant It follows, then, that the greater the load per engine the more economical is the working

In his comprehensive volume on *Railways of To-day*, Mr Cecil J Allen gives an interesting illustration of the economic disadvantages of using small capacity wagons To transport 1,000 tons of coal in wagons of 10 tons' capacity each would require a train of 100 wagons measuring 2,000 feet in length If we assume the 'tare' or empty weight to average 6 tons per wagon, a total

tare of 600 tons would have to be hauled in addition to the load, making a gross train weight of 1,600 tons If the same load were carried in wagons of 20 tons' capacity, having 9 tons tare weight, a train of only 50 wagons would be sufficient, having a total length of 1,225 feet, and the gross train weight would be 1,450 instead of 1,600 tons

Thus, by using 20-ton wagons instead of 10-ton, the train length in this instance would be reduced by 775 feet and the gross weight by 150 tons The reduction in length means that the train occupies a shorter stretch of line, and therefore a shorter length of siding is required to 'park' it The reduction in weight means, of course, that less locomotive power is needed for the hauling of the train and, therefore, the consumption of coal is reduced

CHAPTER X

# SIGNALLING

In bringing our story of railways up to this stage we have seen how the route is chosen, the track built, and the locomotives and rolling-stock provided The next question is, What provision is made for the safe and speedy running of the trains? This brings us immediately to the signalling system and to the part it plays in the work of a railway

The signalling system has two main duties to perform first, to safeguard the passengers, the staff, and the rolling-stock, second, to facilitate the flow of traffic and, by so doing, to increase the carrying capacity of the line

If the stream of traffic has to be restricted because of the lack of signalling facilities or because of their shortcomings, it is as if a certain length of the line were put out of action On the other hand, if the signalling system that is adopted makes it possible to increase the stream of traffic, that is tantamount to adding to the length of the line, since it makes the existing line more effective It will be noticed, therefore, that the signalling system is not concerned only with safety, but that it has an important effect upon the amount of traffic output from a given section of line with a given quantity of rolling-stock

The question of the flow of traffic is not the same as the question of the speed of the trains Increasing the traffic flow means shortening the time-intervals between successive trains, and this, in turn, means a better use of a given line and of a given amount of rolling-stock On the other hand, by increasing the average speed of the trains a smaller quantity of rolling-stock (including engines, coaches, and wagons) can do the same amount of work, because of the more frequent 'turn round'

In this chapter we shall be concerned with the sig-

nalling system as a means, first, of ensuring safety, and, second, of increasing the capacity of the track. By the capacity of the track is meant the amount of traffic that can be run over a given length of line in a given time.

The earliest railways had no signalling system. The responsibility was thrown upon the driver to keep his train under sufficient control to enable him to stop it short of any obstruction that he might see on the line. When signalling was initiated, the earliest form of signal first used was human—a 'railway policeman' furnished with a flag. It was soon realized, however, that this was not sufficient to ensure safety, and the next step was to bring into operation a system of trains worked by time-intervals. That is to say, a fixed interval of time was imposed between the departure of one train and the departure of the next along the same line. The interval was calculated to provide a sufficient distance (now termed 'headway') between the tail of one train and the head of the next following train. There was no means of knowing that a train had in fact arrived, but, on the invention by Wheatstone and Cooke of the electric telegraph, it became possible to learn by telegraph of the arrival of the trains at the far end of the section.

This put a powerful instrument into the hands of the signal engineer, and the fixed time-interval system was displaced by the *block system*. In the block system, instead of a fixed time-interval we have a varying interval depending upon the time actually taken by the particular trains concerned to pass over a definite section of the line. Strictly speaking, the block system is a space-interval system. Under the time-interval system the line was assumed to be clear after a certain fixed period of time had elapsed. Under the block system the line—or rather, a section of the line—is assumed to be blocked until the fact that it is clear has been established by definite telegraphic inquiry and answer.

Under the block system the whole line is divided into

successive lengths called block sections. Each section is guarded by a set of signals under the control of a signalman, whose duty it is not to give permission for a train to proceed from his section to the next until he has received definite information from the signalman ahead that the section into which the train is about to enter is clear.

For the working of the block system two signals are essential, the distant signal and the home signal. It is the function of the distant signal to give a preliminary warning to the engine driver whether the home signal to which it relates is at 'danger' or at 'clear'. If the distant signal is at 'danger', then, although the driver may pass it, he must expect the home signal to be at 'danger' and he must prepare to stop his train. In order that the distant signal may be clearly distinguished, its semaphore arm is notched at the free end, hence this signal is often called a 'fish-tailed' or a 'swallow-tailed' signal. The semaphore of the distant signal is also usually painted yellow instead of red.

The home signal is the name given to the signal which, under normal circumstances, is used to protect junction points and points leading to or from sidings by the line. There is one other signal which may be noticed, namely, the starting signal, such, for example, as the signal at the end of a railway platform, the duty of which is to control the entry of trains into the section in advance.

It was about the year 1838 that distant signals were introduced in definite relation to home or to starting signals. This innovation was the first effort made to increase the capacity of the track, by enabling the engine-driver to run with greater confidence. Up to that time signalling developments had been concerned almost exclusively with increasing the factor of safety.

It will be clear then, from what has been said above, that the home and starting signals are 'stop' signals, whereas the distant signal is essentially a 'repeating'

signal, since its function is to repeat the position of the corresponding stop signal at the time when the train passes the distant signal At what distance from this stop signal should the distant signal be placed? This must depend upon the momentum to be overcome and the braking power available in the case of the most difficult train likely to pass over that particular section of line By the 'most difficult train' is meant, in effect, the train requiring the most effort to stop

Obviously, if the distant signal be placed too near the stop signal, the engine-driver may be called upon to bring his train to a standstill within a distance too short for the operation On normal lines the distance between the distant signal and the stop signal is usually from half to three-quarters of a mile On the electrified lines of the London underground railways, however, where, strictly speaking, there is no separate distant signal but a repeater on the starting signal which performs the same function, the distance is sometimes as short as a hundred feet

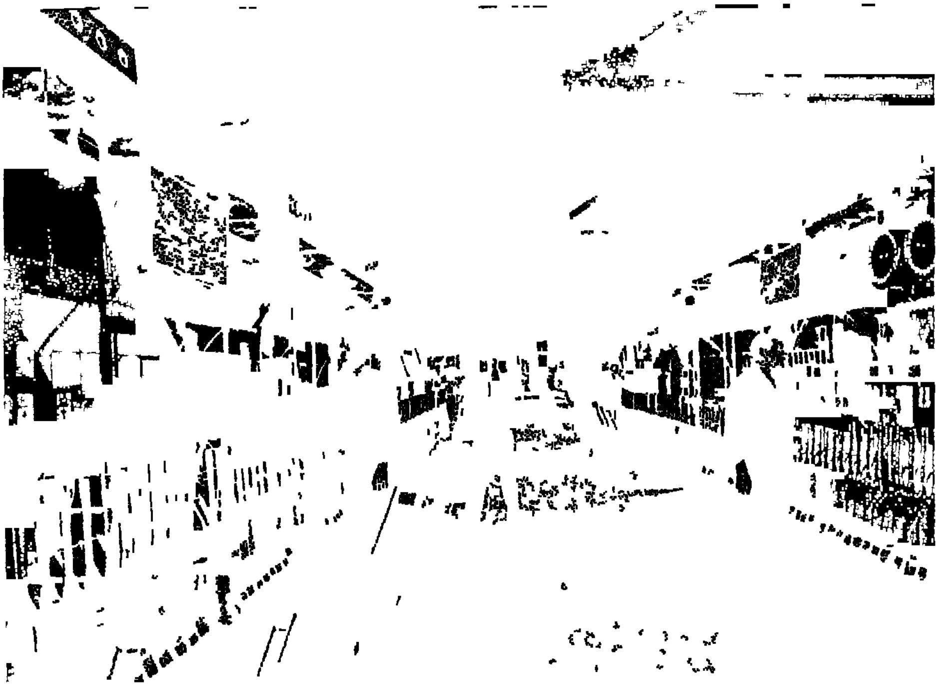
A good deal of elaborate apparatus—electrical and mechanical—and many ingenious instruments are used to-day in the signal-box, on the signals themselves, and at the points of the track The arms of the semaphore signals carry coloured glasses, which move in front of lamps, electric or oil-burning, attached to the signal posts, so that the position of the semaphore arm is indicated at night by the colour of the light transmitted by these glass screens In railway stations, sidings, and goods yards there are also signals at ground level, to govern the passage of points that lead from one line to another One of the most useful adjuncts to the telegraph is, of course, the telephone, which was invented later

In the early days of the block system and with the equipment then available it was usually necessary for the engine-driver to slow down in approaching junctions, because, although the signals might be in the

'clear' position, it did not follow that the points were properly set for the route the train had to take This latter operation—the setting of the points—was quite independent of the setting of the signals A mechanical device, known as an interlocking frame, was introduced, which interlocked the points and the signals, so that it became mechanically impossible for the signalman at a junction to lower the signals unless the corresponding points for those particular signals were first properly set This development not only made for increased safety but, by making higher speeds possible for trains running through junctions, it also increased track capacity

In 1882 the interlocking system was carried a stage farther, and a means of interlocking signal with signal was adopted in order to avoid the possibility of mistakes in the block telegraph acceptance of trains Thus an interlocking block system prevents the signalman at one cabin from lowering his last stop signal until the train has been accepted by the cabin in advance It also prevents the signalman at the cabin in advance from giving permission for a train to approach from the cabin in the rear until the previous train has passed and his section is clear In Great Britain, at the present time, one by one the large mechanical interlockings at big junctions and terminal stations are being replaced by electrical interlocking systems, which were first introduced about 1929

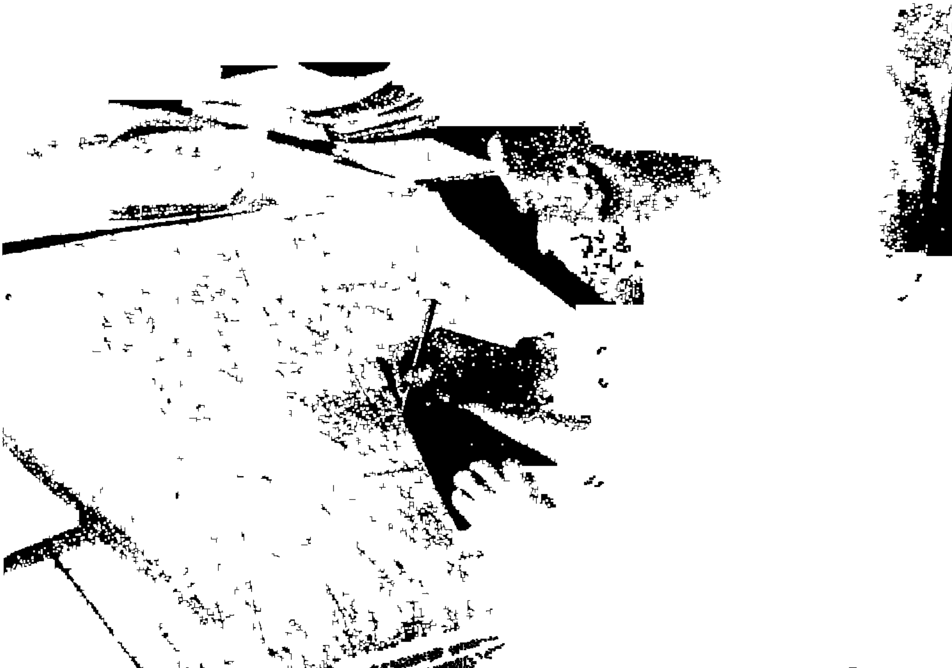
As traffic has increased, so the need has grown to get an increased number of trains over the existing lines of British railways in a given time, in other words, to increase still further the track capacity without having to build new track. Consequently, there has been of recent years a gradual abolition of the standard practice of equipping each block section with distant, home, and starting signals A new system is being rapidly developed under which each signal can itself perform the functions of both a distant and a stop signal In this

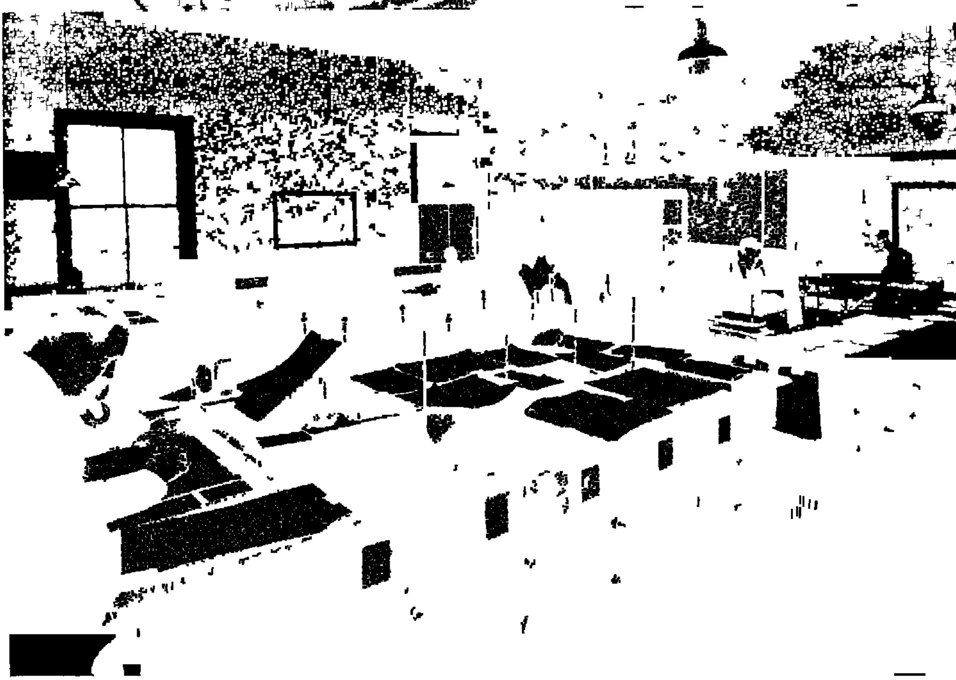


*Above* Interior of Waterloo all-electric signal box
*Below* Waterloo 'A' box—a manually worked cabin

*By courtesy of Southern Railway*

PLATE 19





*Above* At work in a train diagram office
*Below* Willesden control office

*By courtesy of L.M.S R.*

way any two consecutive signals, working in conjunction, constitute a block system

In connexion with these developments 'upper-quadrant' semaphore signals are coming into use, some of them having three positions for the 'arm' horizontal for 'danger', at an angle of 45° in the *upper quadrant* for 'caution', and vertical for 'clear'

A still more recent development which is being rapidly extended is the use of colour-light signals in place of semaphores (see Plate 17) These colour-lights give three indications red, signifying 'danger', yellow, 'caution', and green, 'clear' On lines where the traffic is dense and there are also great differences in the speeds of trains there has been a further development in the installation of four-colour signals The 'four-aspect' type of colour-light signal gives the following indications

Red light for 'Danger—stop'
One yellow light for 'Caution—the next signal is at "danger", be prepared to stop'
Two yellow lights for 'Warning—the next signal is yellow, be prepared to pass it at restricted speed'
Green light for 'All right, proceed at the usual speed'

It will be realized that, by means of these signals, the driver can ascertain not only whether it is safe for him to proceed but also how fast he may go In other words, the effect of this 'multiple aspect' signalling is, so to speak, to lengthen the driver's view of the line ahead of him The four-aspect system allows fast trains to follow each other at intervals of 2½ to 3 minutes

Recent research work has resulted in increasing the brilliance of the source of the illumination used in signals, and this improvement, combined with the use of coloured glasses that transmit a much greater proportion of the light than was formerly the case, has made it possible for these colour-light signals to be seen at great distances, even in bright daylight The consequence is

that the daytime use of colour-light signals instead of semaphore signals is being rapidly extended

Among other developments we may notice the use of *power signalling*, in which some form of power is used in place of the muscular power of man for working the signals The power usually employed is electricity or compressed air—or sometimes a combination of both By substituting power signalling for the older manual method many advantages are gained Greater speed of operation is attained, it is possible to operate signals and points at a much greater distance from the signal-boxes, fewer signalmen are required because the signalman's work is made much less laborious, moreover, a very much smaller box and frame to house the signals are sufficient, so that valuable ground space can be saved (Plate 18)

On certain lines or sections of line still further economies have been secured by installing *automatic signalling* In this system the trains are made to do their own signalling By means of an electric current conveyed by the track the passing of a train puts the signals to 'danger', and they are kept at 'danger' until the train has travelled so far ahead that the protection is no longer necessary Furthermore, by the use of track circuits it is possible to prevent the signalman from accepting a train from the signal-box in the rear or from lowering the signal that protects the train standing on the circuited track

In this automatic signalling system the electric current has to flow from the track through the wheels and axles of the train back to the track In order that this might be done, it was necessary not only to 'bond' the rails, but also to bond the wheels and axles of the vehicles—i e to ensure that there was electrical connexion from rail to rail and from wheel to axle It took many years to solve the problem of properly bonding the wheels so as to make sure that the path through the wheels and axles was electrically conducting. When this

was achieved, it then became possible to work the signals by means of the track circuit, and to do so either independently of the action of the signalman or in conjunction with it

Sometimes it may be necessary to make connexions between a line that is worked with automatic signalling and another line which is worked in the non-automatic way In these cases a system of *semi-automatic signalling* is employed In this system the movement of the signals can be controlled, as may be needed, from a signal-box During the periods when it is not necessary to use the signalbox control, the working reverts to the automatic method

A question often asked in connexion with automatic signalling is, What happens if the current of the track circuit fails? The result is immediately to put all the signals concerned at 'danger' and so to bring all trains to a standstill Thus failure of the automatic apparatus cannot result in accident but, at the worst, leads only to delay and inconvenience

Automatic signalling has certain obvious advantages The wages of the signalmen who would otherwise be needed are saved, the capacity of the line is increased, because the signals are released the moment the train passes the clearance point and no time is wasted in exchanging bell signals between signalmen, as is done on the block system There is also a saving in the costs of constructing and maintaining signal-boxes and all the necessary apparatus to connect them to the signals

Almost all single lines are worked by some form of *token system*, that is to say, the driver is not permitted to pass along a given section of the single line unless he has on the engine a token, which may take the form of train staff, electric train tablet, or electric staff or key There must, of course, be only one token available at a time for a given section of line

To prevent signals being ignored, automatic train-stops are used on the underground lines of the London

Passenger Transport Board Fitted to every train is a 'trip' valve, i e a cock with a handle hanging vertically, the cock being closed while the handle is in this position When the cock is opened it allows air to escape from the brake-pipe, and thus the brakes are applied Fixed to the track, at the site of each signal, there is a 'trip' arm When the position of the signal is at 'clear', this arm lies horizontally below the track When the signal goes to 'danger', the arm goes to the vertical position and thus intercepts the handle of the trip-valve of any train attempting to pass it, in this way opening the cock and applying the brakes

On the main lines of Great Britain not very much has yet been done in the way of providing automatic train-stops, except on the G W R , where some 2,130 miles of the main lines have been, or will shortly be, fully equipped with an automatic stop system, affecting about 1,320 signals and 2,000 locomotives This system gives *audible* signals to the engine-driver in the cab of the locomotive When a 'distant' signal equipped with this apparatus is passed by a train at the 'all right' (off) position, a bell rings in the engine cab When a signal is passed at 'caution' (on), a siren sounds, and at the same time the continuous brakes on the train are automatically applied The application of the brakes and the sounding of the siren continue until the engine-driver acknowledges the signal by lifting a small handle on the apparatus in the engine cab

The apparatus installed on the permanent way consists of a ramp fixed between the running lines at or near each distant signal The ramp consists of a baulk of timber about 40 feet long, on which is mounted an inverted T-bar, the highest point being 3½ inches above the rail level The corresponding equipment on the locomotive includes a shoe or plunger fixed on the centre line of the engine The plunger projects to within 2½ inches of the rail level, and is consequently lifted each time the engine passes over a ramp By

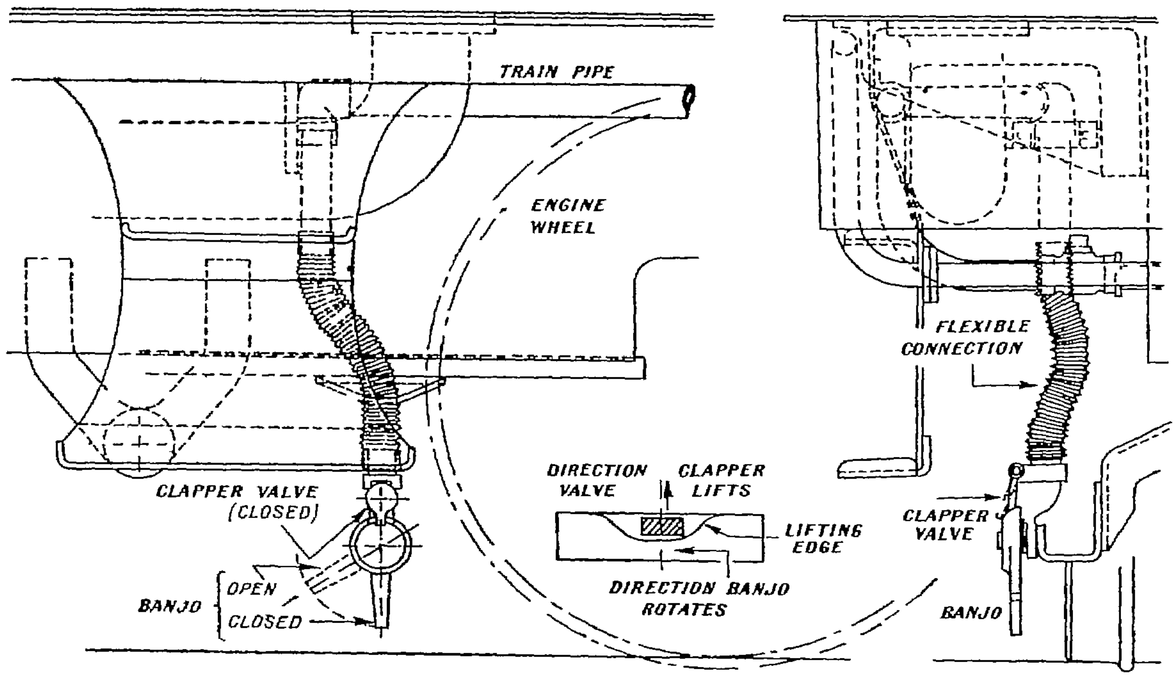



Fig 16 Trip-cock gear

means of electric circuits, the ramp is energized when the signal is in the 'clear' position and electrically dead when the signal is in the 'caution' position An electric battery and circuit on the locomotive cause changes in the electrical condition of the ramp, through its contact with the plunger These changes operate either the bell or the siren and brakes according to the position of the signal

This use of automatic stops is, however, likely to be further developed, for it promises to effect economies in the cost of fog-signalling At the present time when fog prevails signalmen are employed to place detonators on the line and to show hand-lamp signals at a large number of fixed signals This, however, is an expensive procedure An automatic stop system has the virtue that it operates as well in fog as in clear weather

Another interesting development in signalling is the use of 'route indicators' at many of the fixed signals which, in some cases, are operated by 'route levers' in the cabins These indicators are often provided at places where a number of routes diverge In one form of route indicator a number or letter is optically projected on to a glass screen, to indicate to the engine-driver the route for which the points are set

It may be interesting to note a few particulars of some of the largest British signal-boxes, taking the number of levers used as a measure of the size of the box The largest is at Glasgow Central Station, on the L M S R , where there is a box of 374 levers, worked by power It is followed closely by the East Box at Bristol Station, on the G W R , which has 368 levers, also operated by power The largest British box worked manually is the Loco Yard box at York, on the L.N E R , which has 295 levers The largest signal-box on the S R is that at London Bridge Station, which has 311 levers, power operated Altogether, on British lines, there are 21 signal-boxes having 200 levers or more

Recent improvements of signalling equipment have done a great deal, not only to increase the factor of safety but also, by facilitating the flow of traffic, to increase greatly the track capacity of existing lines In this way capital has been saved that would otherwise have had to be expended in the construction of more lines One distinguished railway authority has said that a good many lines would have been built as single lines if the modern methods of signalling had been available when they were originally constructed

CHAPTER XI

# OPERATING PASSENGER TRAFFIC

THE work of the operation department of a great railway includes all matters relating to the timing of trains and to the making of separate working programmes for locomotives, carriages, and train crews (drivers, firemen, and guards) respectively, and, in general, all questions that concern the operation of trains, whether passenger or freight In this chapter we shall be concerned with passenger traffic

The staff of the operating department of a railway includes district controllers, station-masters, inspectors, and supervisors, signalmen and gatekeepers, engine-drivers, firemen, and guards, ticket-collectors, porters, and shunters, and certain other grades of workers Usually this varied staff is under one chief operating manager

We may begin by considering a few matters concerned with the passenger stations at which railway journeys usually begin and end The two principal factors that determine the maximum train capacity of a railway passenger station are, first, the length and number of platform lines, and, second, their layout and the layout of the lines that communicate with them A very great deal of thought is given to the planning of the rail approaches to a station, in order that the departing and arriving trains may interfere as little as possible with each other At the larger stations the operation department issues periodically, for the use of the railway staff, pamphlets which show (1) from where, at what time, and at which platform each incoming train will arrive, (2) what happens next to the engine, the set of carriages, and the guard respectively; and (3) from which platform and at what time each outgoing train will depart

The regular shunting is also arranged beforehand, as

far as possible. In fact, everything that can be planned ahead is so planned, in order that haphazard working and last-minute decisions may be reduced to a minimum. It is scarcely an exaggeration to say that at a busy terminal railway station the work of every man employed, from the station-master to the junior porter, is planned in advance for almost every minute of his working day or night.

Of course, last-minute alterations have to be made occasionally, especially on days when extra trains are running, and to make these changes promptly, so as to disturb as little as possible the planned arrangements, the station staff must have been thoroughly trained and have a high degree of technical efficiency.

Here we may note a few particulars of some of the largest passenger railway stations in Great Britain. It is difficult to say absolutely which is the largest, because so many criteria have to be taken into account as to the meaning of largest. Is it to be determined by the number of platform lines, the total length of the platform faces, the area occupied by the station, or the number of trains entering and leaving in twenty-four hours? The reader may draw his own conclusions from the following data.

| *Station* | *Waterloo* | *Victoria* | *Liverpool Street* | *Manchester (Victoria & Exchange)* |
|---|---|---|---|---|
| Railway | S.R. | S.R. | L.N.E.R. | L.M.S.R. |
| Total platform lines | 21 | 17 | 18 | 22 |
| Number of trains in 24 hours | 1,555 | 1,052 | 1,063 | 1,000 |
| Area of station (acres) | 24½ | 25 | 16 | 23 |
| Total length of platform faces (feet) | 14,804 | 16,643 | 11,410 | 13,947 |

The longest railway station platform in the world is at Sonepur, on the Bengal and North Western Railway, India, which has a length of 2,415 feet The longest platform in Great Britain is at the combined Victoria & Exchange Station, Manchester, of the L M S R It is 2,194 feet long

Among other activities of the operating department of a railway let us consider the business of collecting tickets It will serve to illustrate how many factors have to be taken into account in deciding upon the method of performing an apparently very simple operation

It was the common practice on British railways until about thirty years ago to collect the passengers' tickets at a special ticket platform at which the train stopped for this purpose just before it reached the terminal station which was its destination This practice has now been virtually abandoned, because, although it is an effective method of collecting tickets, it is costly in staff, it adds time to the train journey (since the train must stop while the collection is being made), and thus it increases the occupation of the line

To-day there are four other methods of ticket collection in general use (1) at the last station at which the train stops before it reaches its destination, (2) on the train before it departs from the starting-point, (3) at a barrier erected at the exit from the arrival platform at the end of the journey, and (4) on the train itself, during the journey In deciding which of these methods to adopt in any given case the governing considerations are the efficiency of the collection (i e are all the tickets collected?), the cost of the collecting staff employed, the effect on the time of the train journey, and finally, the effect on the occupation of the line

Collecting tickets at the last station at which the train stops before the destination has the disadvantage that it adds time to the train journey and increases the occupation of the line

To collect tickets from the train before it starts may be rather costly in staff, and usually it requires each carriage door to be locked immediately after the collection is completed from the carriage—which may easily be a nuisance to passengers and to staff

The collection at a barrier as the passengers leave the arrival platform is economical in staff, it does not add to the time of the journey or to the occupation of the line, and it is efficient, except in one particular—it does not of itself detect passengers who travel (absent-mindedly or otherwise) first-class with third-class tickets This method of collecting tickets is becoming more and more the standard practice at large stations

From all points of view, except that of the cost of staff, the best method of ticket collection is to collect on the train itself, though, obviously, this procedure can be adopted only on corridor or vestibule trains

It may seem that more space than was desirable has been given to this relatively simple business of collecting bits of pasteboard from passengers But the example was deliberately chosen to illustrate how many and varied factors may be involved in even the simplest job concerned with railway operation

Let us turn next to a much more complicated task—the making of time-tables It might be hastily assumed that the construction of a time-table of trains was likely to be as dull and dreary a task as the compilation of a calendar or the making of a ready-reckoner In fact, the making of railway time-tables is a complicated and fascinating business, which forms a whole-time occupation for a very large staff of experts specially trained for the work

In Great Britain two thoroughgoing revisions of the existing time-tables are made each year, one for the summer train service, which comes into force in July, and the other for the winter service beginning during September The first preparations for these revised time-tables must be made many months in advance—

for example, for the summer service in the preceding October About that time conferences are held among the principal officials concerned, and the working of the trains during the summer service that has just ended is carefully reviewed Later on the higher officials decide what are the principal alterations to be made

Before we go farther let us realize that a railway time-table is a most complicated and delicate structure, pieced together with the greatest pains, and any—even the slightest—disturbance of it may have far-reaching consequences difficult to foresee As has been well said, a time-table is like a castle of cards, liable to be ruined by clumsy meddling with a single card For example, the alteration of the time-schedule of a single long-distance express train will affect the times of numerous connecting trains all over the system concerned

Before the actual construction of a particular time-table is begun there are many factors to be considered For example, account must be taken of the number and the tractive capacities of the engines that will be available to work the trains at the speeds proposed by the time-table It is useless to plan a time-schedule for a particular train that involves a speed of, say, 60 miles per hour, if there will be no engine available capable of hauling that particular train at that speed

The method employed in the actual construction of a time-table is what is called in mathematics a 'graphic' method, and in railway language is known as 'diagramming' the trains We can understand it best if we study a typical train diagram, and for this purpose a reproduction on a reduced scale is given of a part of such a diagram (See Fig 17 between pages 120–121, and Plate 19 )

If we examine the diagram we shall notice that, on the left-hand side, the stations, junctions, and sidings of the portion of the route concerned are set out vertically On the right-hand side the paper is divided into squares and the twenty-four hours of the day are marked hori-

zontally, each hour being divided into thirty equal parts, so that horizontally each square represents two minutes In mathematical language, distance is plotted against time, the ordinates representing distances and the abscissae intervals of time

Running more or less diagonally across the diagram are lines which represent the time-paths of the trains As we read from left to right across the diagram, the up trains are represented by the diagonals that slope downwards, and the down trains by the diagonals that slope upwards It will be clear that the faster the train, the steeper must be its path on the diagram

Each stop of a train is marked by a horizontal break or line in its path opposite the station, junction, or siding at which the stop occurs The longer the stop the longer, of course, the horizontal break It is obvious that for any particular line the down diagonals must not cross each other anywhere, and, similarly, there must not be any intersection of one up diagonal by another, for such an intersection would mean that two trains on the same line would be at the same point at the same moment

In order that one train may pass another running in the same direction on the same line, the leading train must stop in a loop-line or in a siding This, of course, will be represented by a horizontal section in the path of that train, and the overtaking train must be so timed that its path crosses the path of the first train at this horizontal part

In order to distinguish the various kinds of trains (e g express passenger, slow passenger, fast freight, heavy mineral, and so forth) different kinds of dotted lines are used for the paths Thus it is easy to recognize the particular kind of train represented by each path-line on the diagram

It will be seen, then, that the diagram gives a graphic picture of the occupation of the line between any two points at any minute of the day Since every train has

its own path on the diagram, it can easily be seen by a study of the diagram how additional trains, such as relief, special, and excursion trains, may be dovetailed into the existing services with the least disturbance

It is from such diagrams that the numerous books of time-tables are compiled The time-tables that are issued to the public are, however, only a small portion of the many time-tables produced by the time-tabling staff For the use of the operating staffs passenger-working time-table books are compiled, which give full details of the movements not only of the passenger trains but also of empty trains and of light engines (i e engines running alone)

With respect to express trains, these working time-tables give, not only the departure and arrival times, but also the times at which the trains are expected to pass all the principal stations and junctions *en route* Thus the signalmen and others of the operating staff are informed when the fast trains should pass important centres of traffic This knowledge enables arrangements to be made for shunting, for repairing the track or for other operations affecting the main lines, so as not to delay the expresses

These working time-tables deal with the trains as whole units, but the time-tabling staff have much other diagramming to do Separate programmes have to be drawn up for the routine working of engines, of carriage sets, and of train crews respectively

The movement of every locomotive must be diagrammed in order that the fewest possible number of locomotives may be called upon to perform the tractive work required, and that light or empty running may be reduced to a minimum In diagramming locomotive movements account must be taken of the fact that there is a limit to the time that the locomotive can be kept continuously in use As a rule this period is taken as from sixteen to eighteen hours at a stretch. In this period, moreover, opportunities must be provided for oiling

the engine, for cleaning the fire, and for fresh supplies of coal and water to be obtained.

Again, it is desirable that each engine should start and end its day at an engine-shed—preferably its 'home' shed—where the equipment for examining, repairing (if necessary), and general preparation for the next day's work is available. It is most important in preparing these engine-working programmes so to balance the trips that a given engine may return home at the end of its day without having had to do any light running.

It is usual for the coaching stock to be made up, so far as is practicable, into complete 'carriage sets', which also have their own home stations. Sometimes these sets work out and home daily. In other cases they may have to be taken away for a period of two or three days from the stations on which they are based. It is essential, therefore, that careful programmes should be prepared for the working and disposition of passenger rolling-stock, in order to avoid having an excess of carriages where they are in little demand and a shortage where they are badly needed.

The maximum weights of the passenger trains must also be prescribed when the time-table is compiled. In fixing these weights careful attention must be paid to the scheduled time of the train. For example, take a case where the normal train-load is 340 tons and the locomotive scheduled to haul the train has a tractive capacity of 350 tons. If an addition of 40 tons be made to the load, then either bad time-keeping ensues or a more powerful locomotive is required; or else 'double-heading' must be employed (i.e. the use of two engines to haul the train).

In regard to the train crews, the turns of duty of each locomotive crew have to be so arranged as to fit in with the duties required by the trains that have been scheduled. Here again it is most desirable that the driver, fireman, and guard should commence work at

their home station and return to that point within their turns of duty Sometimes turns have to be prescribed that involve the men lodging away from home It is clear, therefore, that great skill is required by the time-tabling staff to arrange schedules of work that will reduce these 'lodging turns' to a minimum, for, of course, they add to the cost of operation

The whole aim in the preparation of these different programmes is to secure the maximum use of the engines and of the crews On the experience of one time-table the next is framed Several months before a new time-table is issued, not only are the public trains scheduled but also the locomotives required for the complete service Throughout all the arrangements of time-tabling and schedule-making the aim is to ensure the most efficient and economical use of each unit—the locomotive, the crew, and the carriage set—while at the same time making adequate provision for an efficient public service

Among the numerous other time-tables, schedules, and programmes issued at regular intervals by the operation department we may mention a fortnightly notice which is issued to the staff containing particulars of all train alterations, together with other information For example, it gives details of any operations that are being undertaken on the permanent way, and of alterations in the hours during which signal-boxes are working

Those sections of the line over which the speed of trains must be reduced, because of the relaying of the permanent way or other operations, are known as 'slacks' In order that the track may be kept in proper condition with the minimum of slacks, there must be constant and close relations between the operation department and the engineering department In planning these slacks ahead, allowance must be made for any exceptional traffic that may be likely or certain to occur on some particular day or days For example, on the

L M S R no slacks are planned between Euston and Liverpool on the day on which the Grand National Steeplechase is run, because of the delay that might be caused to the very heavy additional traffic called for on that day

In order that the drivers of fast trains may be warned in time of the whereabouts of these slacks, a sign is erected beside the track, about half a mile away from

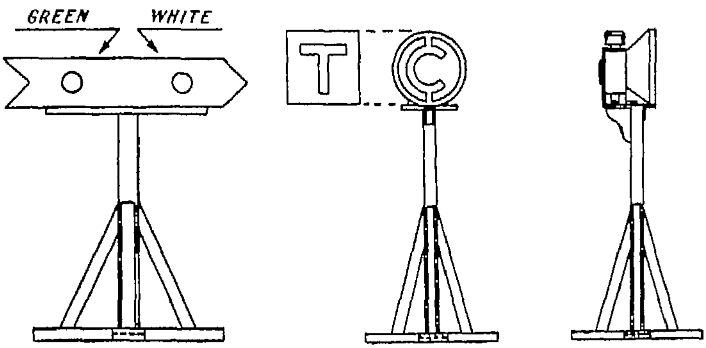



FIG 18

the point where the slack begins, consisting of a horizontal green board fish-tailed at the left-hand end and pointed at the right-hand It is illuminated at night with a pair of lamps, green and white, side by side Just where the work begins and speed must be reduced, a letter 'C' (for 'Commences') in black on white opal glass (illuminated from behind at night) is erected A corresponding letter 'T' (for 'Terminates') erected at the end of the stretch of line under repair shows the engine-driver where he may resume normal speed

It should be remembered, however, that, although the operation department may propose in advance all these schedules and times, yet the weather and a hundred other circumstances may upset the best-laid schemes The slacks, obviously, are likely to disturb

any time-table Again, the coal supplied to a particular engine may be below standard quality and the fireman may not be able to maintain the requisite steam pressure for the speed scheduled Sometimes there may be a temporary shortage of locomotives in some particular locality, with the consequence that an engine may be provided of a type not equal to the task of maintaining the speed scheduled for that train An unusual and unexpected number of passengers for a particular train or an abnormal amount of luggage may also cause delay

Unfortunately, one delayed train may lead to delays to others all over the system, and may even affect the running of trains on other systems It has been recorded, indeed, that the late running of a certain mail train on the old Highland Railway actually affected the working of a G W R train in Cornwall on the following day

If one considers the very great complexity of the work of the operation department of a big railway system and reflects on the numerous and varied contingencies, any one of which may 'throw a spanner' into the delicate mechanism so elaborately and carefully pieced together, it seems almost marvellous that any train should arrive in time Yet statistics taken over our main British railways show that more than 90 per cent of the millions of trains run in the course of a year arrive either to time or not more than five minutes late

## CHAPTER XII

# OPERATING FREIGHT TRAFFIC

THERE is one fundamental difference between passenger traffic and freight traffic  Passengers are free to join or to leave a train at any station at which the train stops and, in so doing, they do not affect in any way the composition of the train (i e  the number and character of the vehicles of which the train is constituted)  Putting it in other words, the passenger is the travelling unit  Moreover, he is an intelligent unit who can generally be trusted to enter or to leave the train at the proper station

If, however, we consider individual freight consignments, it is clear that they are not intelligent and they cannot be loaded into, or unloaded from, the freight vehicles sufficiently quickly to make it practicable for this loading and unloading to be done at any place at which the train stops  Consequently, in freight traffic it is the vehicle itself, together with its contents, that becomes the conveyance unit  It is because of this peculiar characteristic of freight traffic that goods yards and 'marshalling yards' have to be provided, in order that the individual wagons may be combined into trains at the commencement of the journey, re-sorted at intermediate yards where, if necessary, they are recombined into fresh trains, and finally dispersed at the end of the journey

If we consider the typical goods station in a large industrial centre, such, for example, as Camden or Nine Elms in London, we have to picture a daily stream of lorries, vans, and other road vehicles coming and going. They bring goods collected within the London area to be forwarded to all parts of the country and to the ports for shipment abroad  They take away for distribution within the London area goods that have come to Camden or to Nine Elms by rail

The first requisite for such a goods station is a group of sidings for the reception and dispatch of the freight trains In these sidings all the incoming wagons are received, and thence they are taken as required to a section of the great goods shed where they will be unloaded Later in the day wagons loaded with goods to be forwarded will be worked from the shed to the sidings Thus the work performed at goods stations has two main phases—shed operations and yard operations

At the goods shed goods are transferred from road vehicles to rail wagons and vice versa Here, therefore, the aim is to get rid as soon as possible of everything that comes into the shed, for it is meant to be a transit shed and not a warehouse In order that large quantities of goods may pass without difficulty through the goods stations everything is done to make the flow of traffic continuous

One recent development in the way of mechanical appliances may be noticed here In the past much use was made of fixed cranes, or cranes such as gantry cranes, that can work only within limited areas These appliances have the drawback, however, that they require the load to be brought within their reach, and this operation frequently causes delay to other essential operations in the goods yard The rapidly growing use of 'containers', to which reference was made in a previous chapter, has accentuated this difficulty It has been largely surmounted, however, by using mobile cranes capable of lifting as much as 6 tons at a time, and by bringing the crane to the load The advantage of these mobile cranes is that they can be operated at any point at any time without interrupting other work

One of the chief functions of a goods station is to convert the several freight consignments into the first conveyance or travelling unit—the wagon load The next important step is to convert this first unit, the wagon load, into a second travelling unit, the train load

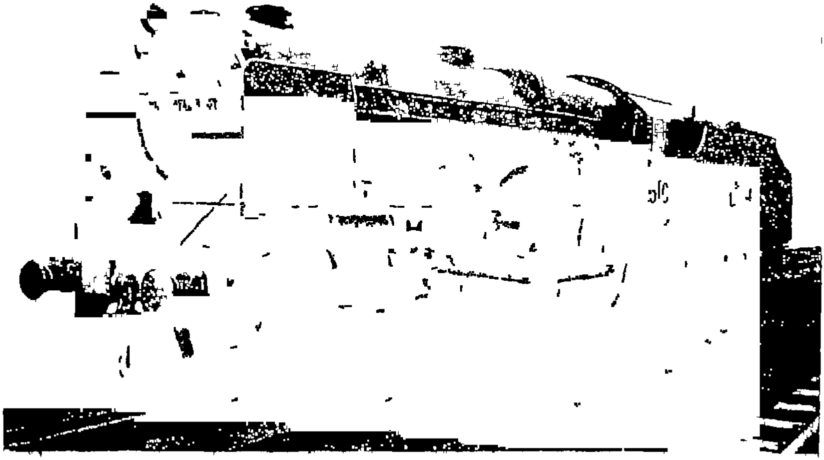
As the loaded wagons leave the goods shed, they pass

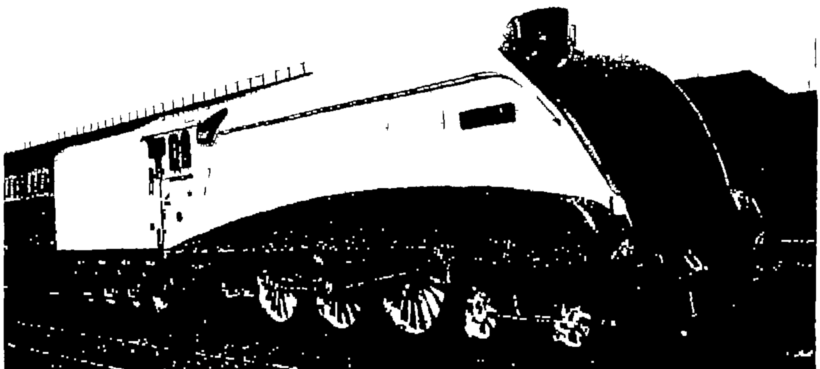
*Above* Edgehill gravity grid Shunter applying brake

*Below* Marshalling yard and control tower, Whitemoor Waggons running from the hump

*By courtesy of L M S and L.N E Railways*

PLATE 21





(1) 4–6–0 'Royal Scot' *By courtesy of L.M S R*
(2) L N E R Streamlined locomotive, 'Silver Link' *Photo 'Topical*
(3) L M S R Streamlined locomotive and train, 'Coronation Scot'
*By courtesy of the 'Railway Gazette'*

into the adjoining sidings There they are combined, according to their respective destinations, to form freight trains, each wagon being labelled to indicate its destination

Now, when such a freight train leaves the goods station, it does not proceed directly to every one of the stations in turn for which it has a wagon consigned, dropping the labelled wagons at their appropriate stations, until there is nothing but the engine and brake-van left at the end of the journey Such a method of procedure would be very wasteful In the operation of freight traffic the ideal is to carry the fullest load to the farthest point in the shortest time Of course, constantly changing conditions and the great fluctuations in the character and amount of freight increase the difficulties of such a task

Experience has led, therefore, to the establishment, at various suitable centres on the railway system, of goods sidings or marshalling yards The main business of these marshalling yards is to receive freight trains made up of wagons for many destinations, to split them up into component parts, and then to form other trains composed of wagons that have a common destination, or at least a common general direction The marshalling yards are to the railways what the sorting offices are to the Post Office

There are two principal types of marshalling yards, namely, flat yards and gravitation yards In the flat yards all the shunting movements of the wagons are effected by locomotives In the gravitation yards the shunting operations are done by gravity, assisted by engine power The sidings of a typical marshalling yard are laid out in three groups reception sidings, upon which the incoming freight trains can stand clear of the running lines while they are waiting their turns to be broken up and sorted, sorting sidings, into which the individual wagons are sorted according to their respective destinations, and departure sidings, which are

in effect reception sidings for the outgoing trains that have been marshalled

We can best understand the working of a marshalling yard if we take a concrete example For this purpose we will select the gravitation yard at Willesden, north of London, on the L M S.R It is the function of this yard to sort and distribute the loaded wagons which arrive from places north of Willesden and carry goods consigned to London or to places south of London,

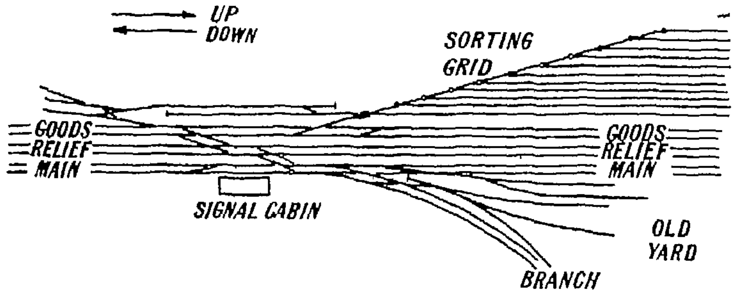



FIG 19 Plan of typical marshalling yard

including centres on other companies' lines Let us see what happens to a typical freight train on arrival at the Willesden yard

As the train comes in on the running lines it is switched on to the arrival sidings of the marshalling yard Here its own engine takes it along one of the reception sidings to a point where the line rises to form a hump The function of this hump will be described very shortly

The engine is now uncoupled and proceeds on a special line, kept for this purpose, right through the marshalling yard to the engine sheds or running sheds beyond. There it undergoes any necessary 'vetting', and it is then sent on its further scheduled duties It will be noted that by this procedure the idle time of the freight engine is reduced to a minimum

Meanwhile the freight train is standing with its leading wagon at the hump The hump is a device to effect the sorting of the wagons, in accordance with their

several route destinations, by using gravity instead of steam as the motive power The line from the reception sidings rises to the crest of an artificial hill and continues downwards, in a gradually decreasing gradient, right to the end of the marshalling yard Beyond the hump the lines branch out into numerous parallel tracks which are the sorting sidings They form what in railway language is called a 'gridiron', or simply a 'grid' (Plate 20)

Next let us note the way in which the newly arrived freight train is split up and its component wagons shunted, each on to its allocated siding in the grid A shunting engine goes to the rear of the train and slowly pushes the train towards the hump At the same time the head shunter, beginning at the head of the train, reads the label of each wagon, marks with chalk on the front of the wagon the number of the siding into which it is to be shunted, and uncouples it from the next following wagon, unless that also is destined for the same siding

In this way the head shunter proceeds from head to tail of the train, while all the time the engine slowly pushes the wagons towards the hump As the first wagon passes over the crest of the hump it detaches itself from the rest of the train and runs down the incline Another shunter, stationed below the hump, reads the chalked number on the front of the wagon as it nears him, and promptly sets the first points so as to shunt the wagon along the appropriate line Furthermore, as the wagon is passing him he applies its brakes in order to slow it down

As the wagon proceeds on its course other shunters stationed at the sorting sidings move other points, so that eventually the wagon reaches its appropriate siding in the gridiron and there comes to rest The next wagon is dealt with in the same way, and thus there is a continuous trickle of uncoupled wagons, each running down from the hump and being switched into its proper berth

These operations make a fascinating spectacle There is the steady, slow 'puff-puff' of the shunting engine as it pushes the train over the hump The wagons in turn break away almost as regularly as the beat of a pendulum, and race down the gradient, very alert shunters run across the lines, to move the proper levers and to apply the brakes to the wagons, and finally the wagons come to rest, each in its proper siding in the grid-iron

Throughout the operation the shunting engine proceeds at a steady, slow pace, moving all the time in one direction Consequently, there is no waste of time or of energy in reversing the engine Moreover, the motive power, which takes the uncoupled wagons from the hump to their appropriate places in the sidings, is gravity, which costs nothing

In a flat yard the wagons are separated and sorted by the shunting engine going backwards and forwards like a shuttle It has been estimated that, in the hump yard, the average freight train can be broken up, sorted, and marshalled in about one-third of the time required for similar operations in a flat yard

At Edgehill, near Liverpool, on what was the original Liverpool and Manchester Railway and is now a part of the L M S R system, there is a marshalling yard in which gravity is the only power used for splitting the trains and for sorting and marshalling the wagons This is made possible by the fact that there is a natural incline near the running lines, and the slope of the ground is used to provide the motive power needed This Edgehill marshalling yard, which is known popularly as the 'Gravity Grid', is, however, unique

At Whitemoor, near March, Cambridgeshire, the L N E R opened in 1929 a new marshalling yard which has many noteworthy features It is a gravity yard but, in the first place, the gradient of the lines from the hump is steeper than that normally used Consequently, the wagons draw apart more rapidly, and the train that

is being split up and sorted can, therefore, be pushed over the hump more quickly

Secondly, in order to prevent the damage that might be caused by running wagons colliding at too high a speed with wagons which have already come to rest in the sorting sidings, the rails at certain parts of the descent from the hump are equipped with brakes of a special type, known as the 'Frolich rail brake' These brakes act by gripping the rims of the wagon wheels as the wagons pass along the sections of the track so equipped Moreover, the brakes are hydraulically operated, not from the adjacent ground but from a control tower that overlooks the yard

Thirdly, as the wagons of the freight train are uncoupled successively before passing over the hump, a card or list is compiled showing to which siding on the grid the respective wagons, or 'cuts' of wagons, are to go

These cards or lists—known as 'cut cards'—are conveyed by pneumatic tube to the control tower Here, by manipulating certain levers, particulars of the sequence of the primary shunting-points in the yard that are to be operated are stored by electrical means in what are called collector-drums By means of track circuits, which work in conjunction with these collector-drums, each wagon or cut of wagons, as it passes through the points leading to the grid, automatically sets the points correctly for the next following wagon or cut of wagons

Thus, by these ingenious mechanical and electrical devices, the wagons are automatically switched into their appropriate sidings, and the braking of the wagons is done by mechanical means from a central control It will be obvious that, as the result of these developments, the speed of shunting operations is greatly increased, while at the same time the man power needed is reduced

At this point we may conveniently summarize the typical operations by which the goods collected from the consignor eventually reach the consignee They are

first conveyed by road vehicle to the goods station, where they are loaded into the appropriate rail wagon and dispatched by freight train, either direct to the prescribed destination or to an intermediate marshalling yard At the marshalling yard the train is broken up The wagons are sorted and also marshalled into station order (that is, from engine to brake van, in the order in which the stations for which the wagons are respectively labelled will be reached on the final journey) The wagons so marshalled into a new train are now sent on the final stage of their journey Sometimes it is necessary to re-sort the wagons at a second marshalling yard before this final journey is begun The wagon —which we saw was the conveyance or travelling unit in freight traffic—having arrived at its destination, the several consignments of freight which it contains are unloaded into a road vehicle and delivered at the respective consignees' addresses

The amount of goods traffic to be dealt with on any big railway system varies widely, and therefore it is not practicable to provide a definite booked service of freight trains as is done for passenger trains Nevertheless, in Great Britain (and to some extent also in other countries) freight trains are time-tabled in advance as far as possible

A booked freight service—i e one in which the times of the trains are arranged beforehand—leads to a more economical arrangement of engine power and train crew It makes possible a more efficient organization of the work that is done at goods stations and marshalling yards, and it leads to a better running of the trains For these reasons, therefore, freight working time-tables, very similar in character to the passenger working time-tables we have referred to previously, are compiled for the information and use of the operating staff Programmes of work for engines and for crews respectively are also issued

It would, however, be wasteful to work freight trains

strictly to these carefully prepared schedules For example, owing to fluctuations in the amount of traffic, the engine of one freight train might run with a part load only, whereas another might be so overloaded as to require double-heading, or it might have to be divided into two trains

Thus there is need for some means by which the several depots at which freight is handled can be kept constantly in close touch with each other, almost up to the last moment Only by such constant contact is it possible to make the best use of engines and of rolling-stock, and to avoid the waste of letting powerful engines do the work that could well be done by less powerful ones, or, vice versa, of calling on the weaklings to perform the task of the strong It was to meet this need that a system of traffic control was adopted, the discussion of which we must reserve for the next chapter

## CHAPTER XIII

# TRAFFIC CONTROL

It was pointed out at the end of the last chapter that, for the sake of efficiency, some centralized form of freight traffic control was necessary This control was first instituted in this country in 1909, on the old Midland Railway, between Cudworth and Toton sidings The improvement that ensued in the working of freight trains was so marked that the control system was subsequently established over the whole of the Midland Railway Moreover, it was extended to embrace the operation of the principal express passenger trains as well as freight traffic Later other railway systems adopted it, and nowadays some form of traffic control is employed on all British main lines

What is traffic control? Under the system of traffic control there are established over the railway at selected points certain control centres These centres receive all the latest, up-to-the-moment information required to enable them to issue instructions regarding the movement of all freight vehicles, freight trains, and train crews in a specified area These instructions may, of course, modify or even cancel previous instructions, in order to meet the constantly changing conditions of railway working

Traffic control might well be called the operating department's nervous system The central ganglion of this nervous system is at the head-quarters of the operation department The threads—or, if you like, the nerves—of the control system pass from the centre, through divisional control offices, each responsible for a wide area, down through district control offices, responsible for subdivisions of each divisional area, until they reach each goods station and marshalling yard on the whole railway system

From selected points within the district area each

district control receives reports by telephone at intervals throughout the day These reports give information of the disposition of all the wagons in the vicinity of the respective reporting point They tell whether the wagons are empty or loaded, and, if they are loaded, the destination or area to which they are to be moved is also given

The district controls in their turn keep the divisional controls regularly informed of the state of affairs within their respective districts Every morning the divisional control office receives by telephone a comprehensive statement relating to the area under its control This statement shows the state of the weather, particulars respecting engine power, brake vans, and train crews available, and the amount of freight on hand

It is on the basis of these 'morning position statements' that the district control office issues directions for the working of the traffic Corresponding 'afternoon position statements' are received later, which enable any necessary modifications to be made in the train arrangements already prescribed Thus each district control office has, at almost every hour of the day, a detailed but changing picture of the state of affairs within its own area—the state of affairs, that is, in regard to the traffic on hand and the engine power, crews, and vehicles available to deal with it

Similarly, the divisional control offices have pictures, though not in such detail, of the state of affairs within the divisional areas The head-quarters of the operating department is also kept fully informed at intervals of the position throughout the whole railway system It will be realized that, by centralizing all the latest information of the freight traffic to be moved, of the engines and train crews available to move it, and of the number of wagons at hand for loading, the control authorities can see the most economical way of working the traffic as a whole

The information that is available, for example, to a

district controller covers a greater area than that obtainable by a goods yard master, whose knowledge is restricted to only a portion of the district area. The district controller, therefore, is enabled to give a sounder decision than can the yard master. A controller can make very considerable savings in engine power, in staff, and in the movements of both loaded and empty wagons. Workings that are no longer necessary can be immediately cancelled, partly loaded trains can be stopped at suitable places to be fully loaded, and a constant watch can be kept on the time of all the men within the control area, enabling overtime or lodging away to be reduced to a minimum.

The purposes of the traffic control system are to economize wherever possible in engine-miles and train-miles, to see that trains are loaded to full capacity and that the wagons are moved as quickly as possible. In short, the aim is to get the fullest load to the farthest point in the shortest time at the least cost. It should be noted, too, that the control exercises a most important function when accidents or other disturbing circumstances, such as fogs, tempests, or snowstorms, occur. The control can then step in to stop certain passenger or freight trains, where desirable, or to divert them to other routes.

The actual operations in a district control room are comparatively easy to follow, even for a layman. There must be an elaborate and efficient telephone system for the receipt and the dispatch of the stream of information and instructions required. The attention of the control staff is called to the telephones by the silent lighting of small lamps, which are mounted on pillars spaced over a long table. Besides supplying the particulars contained in the morning and afternoon position statements, the various reporting points keep the control staff advised of the exact movement of each freight train within the control area.

As these reports are received, each train moving

within the area is represented graphically, either on large diagram boards hung on the walls or on diagram sheets On these diagrams the names of the stations and signal-boxes are shown in their respective positions, as well as such features as marshalling yards, standage sidings, and relief sidings, figures being added to show the lengths of the different lines in the sidings or the number of wagons each line will accommodate

In cases where diagram boards are used a card is affixed on the board to show the position of each train, the colour of the card varying in accordance with the character of the train On the card itself are entered certain details, such as the number of the engine, the load, the names of the driver and guard, and the times at which the train actually passes the more important timing-points Throughout the day and night each card is moved gradually across the board, in accordance with the reports received of the position of the train it represents Thus the state of affairs at almost any moment in regard to the whole of the freight traffic within the control area concerned is visible at a glance

What has just been said refers mainly to freight traffic The control of the passenger traffic, which was first introduced on the former Midland Railway in 1917, extends only to the principal express trains and does not, as a rule, include local services The exact position of the principal express trains in the respective divisional areas can be seen at any moment of the day or night on passenger train control tables in the divisional control offices

On these tables long brass slides represent each main line These slides carry clips holding cards, each of which represents an express passenger train On these cards the necessary particulars of the trains are entered In accordance with information received by telephone from time to time throughout the day and night, the clips are moved along the slides, so that the position of each express is shown In this way the control keeps a

close watch on the movements of the principal express passenger trains running over the whole system

If circumstances arise requiring extra rolling-stock to be attached to any train, a request must first be made to 'control', which then gives full instructions where the required vehicle may be found and in what position in the train it is to be marshalled (i e at which end or where else) The movement of every horse-box, live-stock vehicle, carriage truck, parcels van, and motor truck is recorded, and no such vehicle may be attached to any train without the consent of the divisional control Thus a close watch is kept on the whole of the rolling-stock running over the line, whether passenger or freight stock

The cost of the control system, both in the equipment needed and in staff, is obviously great, but all railway authorities are agreed that traffic control is the most satisfactory method of railway operation, especially in regard to freight traffic Not only does it help to speed up the running of the trains, but it effects considerable economies by facilitating the better loadings of trains and a better use of the engines and staff

# CHAPTER XIV

## THE LOCOMOTIVE ON THE ROAD

IN this chapter we are to see something of the locomotive at work on the road  As was indicated previously, the engine shed is virtually a 'stable' where the locomotive—the 'iron horse'—is regularly 'bedded and vetted', in order that it may be kept in good condition  The ideal practice is for every engine to return to its own shed once in every twenty-four hours, in order that it may be examined, cleaned, and, if necessary, repaired  The staff of the engine shed consists of mechanics and cleaners  The mechanics carry out what are called 'running repairs', i e  those minor operations that can be done without having to withdraw the engine from service and return it to the locomotive works  The work of the cleaners is indicated by their name, from them the drivers and firemen of the future will be recruited

For each locomotive a schedule of work is carefully planned ahead, providing for a definite sequence of trains to be hauled from the beginning of the week to the end  These schedules of work are known as 'rosters'  The various rosters are arranged in groups, in accordance with the relative difficulty of the tasks involved, and the drivers and firemen similarly are formed into 'links', according to their experience and skill, each link being responsible for manning one group of the rostered workings

On graduating from a cleaner into a 'passed fireman', the novice enters the lowest link, his work being confined to shunting engines  He advances by degrees to freight engines, then to passenger engines, then to express engines, and last of all to the 'top link' at the shed, which involves all the most responsible express duties  The next stage in his progress is graduation from 'passed fireman' to 'passed driver', after which all the varied stages just mentioned—shunting engine, freight engine,

passenger engine, express engine—must be passed again Finally—perhaps some twenty years after his early days as a cleaner—he may be entrusted with the proud task of driving a famous express, such as the 'Cornish Riviera Limited', or the 'Royal Scot', or the 'Flying Scotsman'

It will be seen, then, that there is no royal road to command of the foot-plate The driver must be perfectly familiar with every yard of the route over which he travels and must know all the signals He must know the position and the steepness of every gradient and the demands that these gradients will make on his engine Furthermore, by the proper manipulation of his regulator and valve motion, he should make the best use of the steam produced by the labours of his fireman His ear must be quick to detect any irregularity in the 'beat' of his engine which might indicate some defective or damaged part It is for these reasons that his experience as a cleaner is so valuable, for in that stage of his career he obtains intimate knowledge of locomotive construction Similarly, during the years he spends as a fireman he acquires at first-hand valuable knowledge of the management of the engine, the production and the use of steam, and the characteristics of the various lines over which he has travelled Thus, when he graduates as a driver, he has already acquired a vast store of varied experience, which is supplemented by systematic instruction given in specially equipped instruction cars

Let us now follow from start to finish the work of an engine crew on a typical journey At a definite time before the scheduled departure of the train to which they have been assigned, the driver and fireman present themselves at the shed and 'book on' for duty The driver first consults the notice board, to see whether there are any special notices affecting the line over which he is to run, e g temporary restrictions of speed owing to track repairs or to engineering works or to alterations to signals The crew now pass to the shed road, on which their

engine is standing, usually with steam raised to a pressure of 100 lb or so

Time is allowed to the driver and fireman, between their 'booking on' for duty and the time fixed for the departure of their engine from the shed, to enable them to make some necessary preparations The driver thoroughly examines the engine and its mechanism, so that he may be satisfied that the various parts are properly adjusted During this examination he charges the different lubricators with oil, while the fireman makes up the fire and sees that the tender has been fully supplied with coal and water, and that the sand boxes of the engine are filled with dry sand

At a definite booked time the engine is run 'light'—i e alone—from the shed to the station platform at which, by this time, the train is waiting This light running must, of course, be sandwiched in between the ordinary trains and it is diagrammed beforehand by the time-tabling staff The fireman usually couples up the locomotive to the train and the guard informs the driver of the weight of the train This information is important, as it will govern largely the driver's method of working his engine The weight of the train is usually reckoned, not by the number of vehicles but by the actual weight of the coaches, which is marked on the ends of each coach and is thus easily ascertainable These weights are, of course, only 'tare' or empty weights, and an allowance must be made for the addition of passengers and luggage The passenger weight even in crowded trains seldom rises to a quarter of the tare weight

Most companies impose certain definite limits to the maximum loads which may be hauled by each different type of engine on the various timings scheduled in the time-tables The fast express trains, both passenger and freight, need more drastic limitations of train-weight if booked times are to be kept If there is likely to be an excess over the normal load, the fact is generally known in advance, and thus suitable preparation may be made

by providing an assistant or 'pilot' locomotive Sometimes, however, extra coaches have to be added at the last moment to meet an unexpected rush of traffic To provide for such a contingency, and also for possible failures of engines, it is the usual practice at terminal stations and other important traffic centres to keep a pilot locomotive permanently in steam

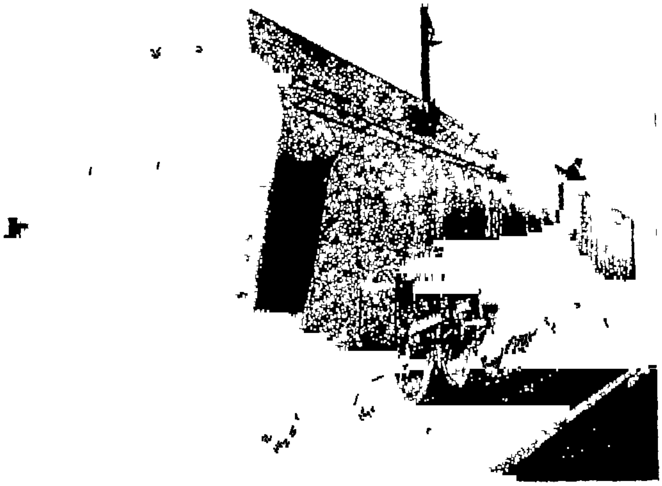
When two engines are attached to a train, the control of the braking is vested in the leading driver because he has the better look-out, though the driver of the second engine is not absolved in any degree from the duty of keeping a careful look-out ahead Often the assistant or pilot engine is attached next the train, with the regular train engine in front By this arrangement the more experienced driver is in control

Nowadays the tendency is to build locomotives with a good margin of power, so that on most of our main lines double-heading occurs less frequently than formerly Sometimes a second engine may be observed at the head of what looks like a very moderately loaded train, but this may be due to the fact that one of the engines is being worked home to its shed, this being the most useful way in which it can make the journey, with the advantage that the occupation of the line is not increased by the independent working of a light engine

Before starting a passenger train an important operation is to test the brakes after the engine is coupled up It was pointed out previously that two diametrically opposed types of brake are in general use the Westinghouse brake, in which compressed air is used to apply the brake-blocks, and the automatic vacuum, which depends on the destruction of a vacuum in the brake cylinder, the pressure of the atmosphere in this case being the force that applies the brakes Engines fitted with the Westinghouse brake can be distinguished by the fact that they carry, usually on the side of the boiler, a donkey-pump or air-compressor, which puffs inces-

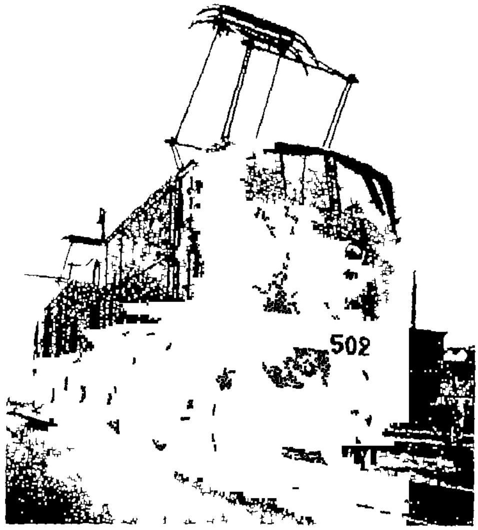
Newest type of Canadian Pacific locomotive

Streamlined Hudson locomotive for the New York Central Railway

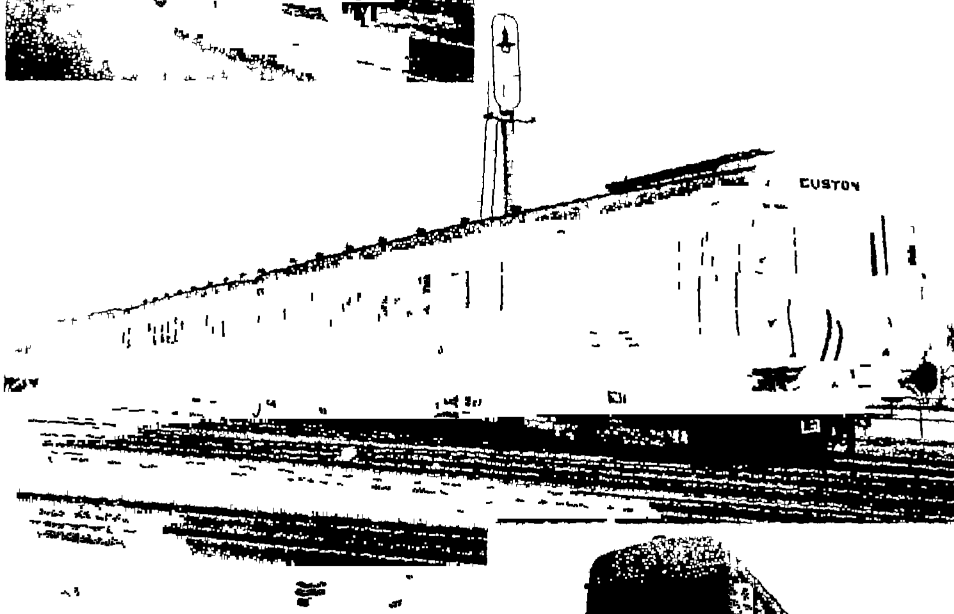


New Streamlined locomotive on the Victorian Railways

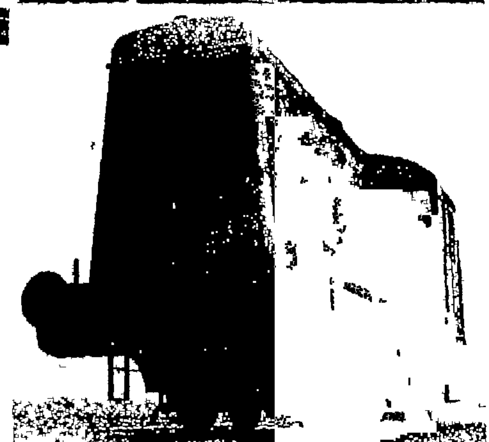
PLATE 23




Electric locomotive, French Railways
Overhead wire system
*By courtesy of the Railway Gazette*



Electric train Third rail system
*By courtesy of L M S R*



Armstrong Whitworth 40-ton Diesel electric shunting locomotive
*By courtesy of the 'Railway Gazette*

santly when the engine is standing Engines that are vacuum-fitted create the required vacuum by means of a steam-driven ejector The roar of this ejector, rather like a lion clearing its throat, may be heard when the engine is standing Sometimes, as, for example, on the G.W R , the ejector is supplemented by a vacuum pump driven by the engine, in which case a characteristic ticking is heard

When the driver receives from the guard the signal to start he opens the regulator that admits steam to the cylinders The regulator is opened gradually at first, because a sudden opening to the full extent might cause the driving-wheels to slip and to 'race' This gradual opening is still more important in the case of freight trains The driver of a long freight train usually stops his train so that the wagons come to rest with the couplings slack and the buffers touching In this condition, when he restarts, he pulls the couplings taut one by one, and thus the load comes gradually on to the engine In these circumstances it will be clear that too energetic a start might snap the couplings If, when the steam regulator is opened, the driving-wheels of the engine slip round on the rails, dry sand is applied, which either falls by gravity on to the rails just in front of the leading pair of driving-wheels, or is blown right under them by means of a steam jet

The fireman's task is also highly skilled work On the run of a heavy express the fireman may have to shovel coal from the tender into the firebox at the rate of something like a ton an hour, and such work involves much more than mere shovelling The art of firing lies in producing just the right quantity of steam at just the right moment When the train is travelling up a long or steep gradient more steam is required, during a spell of easy running downhill or on the level, less steam is required The place in which the fuel is put in the firebox must be chosen with care, in order that the combustion may be even and thorough Sometimes the coal is placed at

the sides, sometimes at the front, and sometimes immediately under the fire-door, the fireman having thus constantly to keep his mind on the science and art of firing

He must look frequently at the pressure gauge of the engine, to see whether by his firing he is maintaining the working pressure of the steam at its proper degree The level of the water in the boiler is also in

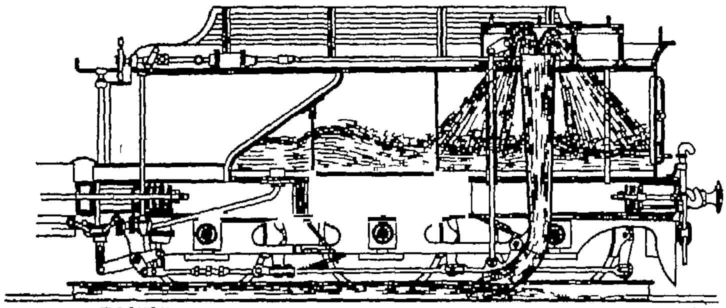



FIG 20 Water scoop in operation

the fireman's care The actual water-level is indicated by a pair of 'gauge-glasses', one on each side of the firebox front, the crew being protected from possible breakage by an outer case of thick glass Care must be taken that the boiler does not become too full, otherwise water will be carried from the boiler down to the cylinders On the other hand, the water-level must not be allowed to fall so low as to uncover the crown of the firebox, as in such an event the boiler might burst

It should be noticed here that the length of run of a locomotive depended originally upon the capacity of the tender Either the tender had to carry a large quantity of water, or the distance between the stops had to be small In 1859 Ramsbottom, who was then the locomotive engineer of the London and North Western Railway, constructed a water trough by means of which the

tenders could replenish their water-supplies while running at high speeds

The trough is laid between the rails for a length of 1,500 to 2,500 feet, on a level section of the line where an ample supply of suitable water is obtainable A scoop is fixed under the tender, and when this is lowered the

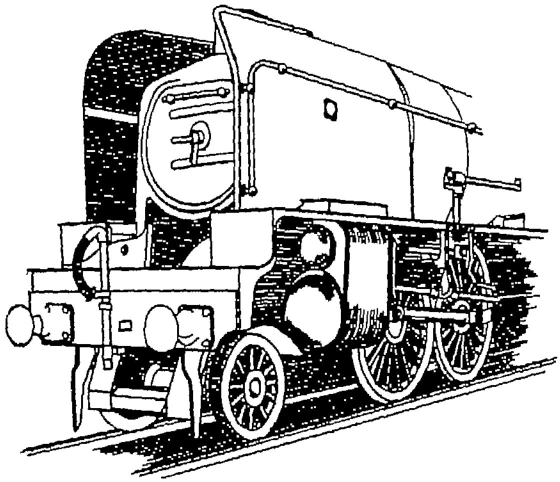


FIG 21 Wind shields

speed of the train forces the water into the tender tank at the rate of about 200 gallons per second, so that a tank with a capacity of 3,000 gallons can be filled in a quarter of a minute The level of the water in the trough is governed by a valve in a manner somewhat similar to that employed in an ordinary household cistern Without the provision of water-troughs it would be impossible for long-distance non-stop runs to be made

The look-out from the engine cab is often obscured by exhaust steam drifting from the short chimney of the modern express locomotive across the front windows of the cab Accordingly, in modern express locomotives wind-deflectors or wind-shields are attached at the front of the engine When the engine is running at speed

these wind-shields create a strong up-draught of air, and so lift the exhaust steam clear of the cab

As is generally known, the working hours of the crews have to be kept down, as nearly as possible, to the statutory maximum of eight per day, but there would be a great waste of locomotive power if every locomotive were worked for no more than eight hours out of the twenty-four Accordingly, the majority of locomotives are double-manned, that is to say, they are worked by at least two different crews during the course of each day On the non-stop run of the L N E R from London to Edinburgh this double-manning is in force, the journey being regarded as too exhausting for a single crew The engine crews are changed midway by means of a corridor down one side of the tender, which communicates through a vestibule with the front coach of the train About the midway point on the journey the relieving crew walk from the front compartment of the train, through the vestibule and the tender corridor, on to the foot-plate, and the crew in charge up to that point pass back to the reserved compartment for the remainder of the journey

At the close of their scheduled working day the engine crew hand over their locomotive either to the crew scheduled to relieve them or, if the engine's labours for the day are also ended, to the running-shed In the latter case the skilful fireman will usually have deliberately let his fire get as low as possible, in order to expedite the work of cleaning the fire-grate, which has to be done before the engine is handed over to the shed staff Finally, before booking off duty, the driver reports any irregularities he may have noticed in the working of the engine or any repairs that he may consider necessary, in order that the shed staff may attend to these matters before the engine is sent out again into service

On receiving the incoming locomotive, the running-shed staff probably first attends to the coaling At many of the larger sheds in this country elaborate coaling

plants have been installed, by which time and labour are saved in filling the tenders with fuel To remove the fine ash from the locomotive's smoke-box, automatic plants, worked by compressed air, are often used Next, the fire is raked out or, at least, cleaned by the removal of the clinker The deposits of soot are removed from inside the boiler tubes by the help of a steam jet, a wire brush, and a swab

The engine then passes to the inspection pits of the shed, where the fitters carry out a thorough examination of the motion parts and any minor repairs needed are effected If heavy repairs are necessary, the engine is withdrawn from service and returned to the locomotive works The boiler of each engine is usually washed out every week, hot water under pressure being used for this purpose Finally, the engine is cleaned Oil and water, helped when needed by bath brick, are applied to remove the dust and grime from the exposed parts A final polish with oily cotton waste to rub up the motion and the paintwork completes the cleaning

The fire is relighted by means of a few shovelfuls of burning coal from the shed furnace, or by the use of bundles of firewood cut from old sleepers To raise steam may require from three to five hours, according to the size of the boiler A member of the shed staff, who is usually known as the lighter-up, is responsible for seeing that each engine is ready for the road, with steam up, at the time scheduled for the engine crew to take over

CHAPTER XV

# ELECTRIC TRACTION

UP to this point we have been assuming that trains are hauled by steam locomotives Although steam is still the prevalent form of traction on British railways and on railways in many other countries, nevertheless, over the world as a whole electric traction is coming into increasing use In some countries abroad—for example, in Switzerland—it is practically the only form of railway traction employed Of recent years electric traction has also developed greatly in Great Britain, especially in connexion with suburban traffic Steam traction is, however, still predominant on our main lines In 1931 a committee under the chairmanship of Lord Weir issued a very full report on the subject of main line railway electrification The report discussed the advantages and the drawbacks of the adoption of electrification and, finally, the cost involved An analysis of that report would be outside the scope of this volume In this chapter we shall confine ourselves to considering briefly some of the ways in which electricity is utilized in railway traction and some of the problems that are involved

Railway electric traction has many forms, but nearly all of them employed at the present day have one feature in common They all use electric motors mounted on the driving axles of the locomotives (where separate electric locomotives are used), or on the driving axles of the motor vehicles employed Such differences as do exist arise in two ways (1) from the nature of the source of the electrical energy, and (2) from the means adopted to transmit this energy from the source to the trains

The electrical energy required may be derived either from an external and stationary power-station or from a source carried on the train itself In the first case the

energy must be transmitted from the power plant to the trains, and this necessitates the equipment of the track either with conductor rails or with overhead lines In the second case, where the source of the electrical energy is carried on the train, that source may be a storage battery or an electric generator (i e a dynamo)

The generator may be driven by a steam-engine (including the turbine and the reciprocating types) or by an internal-combustion engine (including both the petrol and the oil engine) The most common form of railway electrification is the system which provides for the electrical energy being generated in a stationary power plant and conveyed to the motors of the train by means of conductor rails or by overhead wires

Let us remind ourselves here, as was stated in an earlier chapter, that the aim of the locomotive engineer is to convert, at the least cost, the maximum amount of the chemical energy contained in the fuel into the mechanical energy of motion This remains the chief aim whether steam traction or electric traction be employed Now the overall efficiency of a machine is the ratio of the effective work done (output) to the energy put in (input) In the case of the best steam locomotive this overall efficiency does not greatly exceed 10 per cent One of the aims in using the rotary turbine instead of a reciprocating-piston cylinder is to increase this efficiency

Electrification tries to attain still greater overall efficiency by using steam in stationary turbine plants to drive electric dynamos and by transmitting the current from these dynamos to the electric motors mounted on the axles of the railway vehicles With the average modern generating station, equipped with steam turbines, with an up-to-date transmission system and with modern motor equipment on the trains, it is possible for electric railway traction to obtain an overall efficiency of 14 to 15 per cent, as compared with the 10 per cent of the steam locomotive

This, however, does not end the argument Against the greater overall efficiency of electric traction we have to put the increased capital cost incurred in providing power stations and the means (whether ground rail or overhead wire) of transmitting the current to the motors When a complete balance sheet is drawn up, the margin between steam and electricity is usually narrow That is why it is at present not possible to state unequivocally, as a proposition of universal application, whether steam traction or electric traction should prevail It all depends on the particular case

For example, in countries like Switzerland and Italy there is abundant water power but no coal Electricity, therefore, can be generated by means of water turbines, and the importation of foreign fuel is thereby avoided Again, in countries where, owing to the prevalence of long tunnels or of other special circumstances, the elimination of smoke is most desirable, it may be worth while to electrify the railways, quite apart from any considerations of economy in fuel So, too, where traffic is very heavy, as, for example, in the suburban districts of London, considerations of overall efficiency may make it well worth while to electrify, despite the increased capital cost involved

Among other advantages, electric trains are always ready for use to their full capacity, there is no time spent in getting up steam, they are simpler to overhaul and to maintain, and can be kept in service for nearly twenty-four hours a day One most important advantage of electric trains is that they can accelerate two or three times as quickly as the average steam train, so that where stops are frequent, as they are in suburban traffic, a higher average speed can be maintained Furthermore, electric trains can be driven from either end, which reduces shunting movements at termini and makes a quicker 'turn round' possible A greater flexibility is also possible in the make-up of electric trains, so that the lengths of the trains may be varied to suit the

fluctuating numbers of passengers travelling at different times of the day

Again, electric traction being cleaner than steam traction, electrification usually reduces expenditure on maintenance, on the painting and cleaning of stations and other structures beside the line, and on the regular cleaning of the coaches Savings are made in the wages of drivers and of firemen in two ways Electric trains can be driven by one motor-man in place of the driver and fireman needed for the steam locomotive Secondly, as the traffic generally is speeded up, fewer trains and hence fewer drivers and guards are needed to maintain the service

On the other hand, it must be understood that the enormous cost of converting a line from steam to electrical working, together with the cost of other improvements without which the benefits of electrification cannot fully be realized, has to be put on the debit side of the balance sheet whenever the question of the electrification of railway services is being discussed

Next, let us take the case in which the source of the electrical energy is a battery of storage cells or accumulators carried on the train A comparatively recent development of this form of electric traction is due to the invention by Dr Drumm of a battery having two very valuable characteristics It is of robust construction, and can be charged and discharged at very high rates, taking into consideration the size and the weight of the battery The complete cycle of charging and discharging, for example, can be repeated as often as twenty times a day It is claimed that a battery weighing 1 ton can do work equivalent to 300,000 ton-miles per year This 'Drumm battery' has been fitted on a small train which operates a shuttle service between Dublin and Bray in Ireland The battery system of electric traction has not been applied extensively in general railway practice, and it is perhaps too early to judge how far it is likely to be developed

A much more promising type of electric traction, in which the source of the electric energy is carried on the train, is the Diesel-electric system, to which reference was made in a previous chapter The Diesel-electric train, like the ordinary electric train, is driven by electric motors mounted on the axles In this case, however, the electric current which actuates the motors is generated by a dynamo carried on the locomotive and driven by a Diesel engine

In recent years there has been a good deal of experimenting, especially abroad, in Diesel-electric traction In Great Britain the L M S R was the first railway to experiment with this form of traction A complete Diesel-electric train was put into service along the coast between Blackpool and Lytham in Lancashire On the L N E R a regular suburban service has been run in the Newcastle district with a Diesel-electric rail-car since February 1932 Again, in February 1933, a Diesel-electric rail-coach was run at express passenger timings and dovetailed into the regular daily service of the L M S between Euston and Birmingham for a period of about eleven days

Speaking generally, the chief advantages of the Diesel-electric system of railway traction are twofold first, the elimination of the very expensive track equipment, whether conductor rail or overhead wire, and, second, the low fuel consumption of the Diesel engine, combined with the fact, already noticed, that a wide range of oils may be used as a fuel It has been estimated that the railways of Great Britain consume annually some 13 million tons of coal, and that oil-electric locomotives, in performing the same work, would require a consumption of no more than 1 6 million tons of oil On the debit side, however, we must notice that one inherent disadvantage is the extra weight necessitated in carrying the source of power on the train itself

In electric traction by means of batteries or by the electrification of the track there is no combustion of

fuel on the train, whether the fuel be coal or oil In steam traction and also in the Diesel-electric engine, on the other hand, coal is burnt in one case and oil in the other Now the elimination of any form of combustion from the train has certain obvious advantages, especially on lines where tunnels are many and long Apart altogether from any question of improving the comfort of travelling by getting rid of smoke, it is worth notice that on steam-operated railways the rails have to be renewed in the tunnels probably twice as often as in the open, and also the cost of such renewal is appreciably higher than the cost of renewing rails in the open It has been stated that on the Swiss Federal Railways, where there are numerous and long tunnels, the substitution of electric traction for steam traction has effected an annual saving of 268,000 francs on this maintenance-of-rails account alone

It may appear to the reader that electric traction, as compared with steam traction, has been getting the best of the argument, but many high authorities still think that there is a strong case to be made out for steam power It is true that, compared with its electric and oil-electric rivals, the steam locomotive has some obvious disadvantages For example, there is the waste involved in producing steam by burning coal in a fire-box There is the expenditure incurred in the conveyance and storage of the coal required and in the removal of ashes and clinkers The enormous amount of water and coal that has to be carried on the tender constitutes a big dead-weight to be hauled Again, there is the heavy cost of boiler repairs to be taken into account and the losses that are incurred when the locomotive is standing by, burning coal but not doing any work

In electric traction we have practically none of these drawbacks Nevertheless, the steam locomotive has been so much improved in detail that to-day it is fulfilling the demands made upon it It is hauling the fastest and heaviest trains in use. and the designer so

far has had no difficulty in meeting the demands presented to him by the operation department Indeed, it is obvious that the possibilities of the steam locomotive are even yet far from being completely developed Great advances have been made of recent years in obtaining a higher thermal efficiency for the steam locomotive, improved methods of balancing have been adopted, which have permitted higher axle loads Boiler pressures have increased from the 50 lb per square inch of the *Rocket* to 250 lb in some of the modern types New designs of boilers, capable of withstanding still higher pressures, and the possible use of other forms of fuel, are two directions in which we may expect still further progress

In this connexion it should be noticed that great improvements have been made recently in France in the design of the steam locomotive These improvements have increased the capacity to raise steam relatively to the size of the boiler used Improvements have been made in the steam circuit, i e in the steam flow all the way from the regulator to the exhaust, which have increased efficiency The front end design in general has been modified to include the double blastpipe and chimney, which minimize back pressure and help the engine to get rid of its spent steam

In recent years wind resistance has been the subject of special study Researches in wind tunnels, with scale models of locomotives and trains, have been carried out In one set of these experiments it was shown that, in the case of a train of ten coaches, 29 per cent of the wind resistance is accounted for by the engine and tender, 8½ per cent by the first coach, and 6½ per cent by each subsequent coach except the tenth or last, for which the proportional resistance is 9½ per cent The results also showed that, at a speed of 60 miles per hour, without any head wind, more than 25 per cent of the power developed by the locomotive is absorbed in overcoming the air resistance It should be added that this

factor of wind resistance becomes important only at high speeds, and the various stream-lined locomotives and trains, such as the 'Silver Jubilee' and the 'Coronation Scot', are modern attempts to avoid the loss of power due to the resistance of the air

On 3rd July 1938 on a test run between Grantham and Peterborough, on the L N E R , the *Mallard*, a streamlined 'Coronation' class locomotive, drawing a streamlined train, to which a dynamometer car was attached, attained speeds of 125 miles per hour for 300 yards and of 120 miles per hour for three miles The maximum speed established a record for British locomotives The world's record for steam locomotives is claimed by America with a speed of 127 2 miles per hour

It is safe to prophesy that the fight between steam traction and electric traction will go on, just as the fight between gas and electricity, or the fight between guns and armour will go on—at least for a time the end of which cannot be seen now

It should be noted that it was not until very late in the nineteenth century that electricity was called into railway service for the purpose of hauling trains The first electrically operated railway in the British Isles was the City and South London tube between the Bank and Stockwell It was opened for traffic in 1890 The Liverpool Overhead Railway, which was inaugurated in 1893, was the first above surface electric railway in the world The Central London Railway was the next tube and was opened from the Bank to Shepherd's Bush in 1900. This railway was known originally as the 'Twopenny Tube', since it charged a uniform fare of twopence for any distance—a practice since abandoned

From the beginning of the twentieth century electric traction has developed rapidly The whole network of the London tubes, which is still being extended, is worked exclusively by electricity, and a considerable mileage of the existing London suburban lines has been converted

from steam to electric traction In Great Britain the electrification of lines hitherto worked by steam traction began in 1903 with the conversion of the Mersey Railway This was followed immediately in 1904 by the conversion of the Liverpool–Southport line of the old Lancashire and Yorkshire Railway and the North Tyneside lines of the old North-Eastern Railway Great Britain has at present about 667 route miles or 1,713 track miles electrified, excluding lines such as the London tube railways and the Liverpool Overhead Railway, which have always been electrically operated

If we take the whole world, the latest figures show that the electrified steam railways now amount to about 16,500 route miles or over 26,000 track miles For the working of these lines approximately 2,000 electric locomotives and 12,000 motor-coaches and trailers are used

It would be too technical for our purpose to enter upon a description of the rival claims of the direct-current system and the alternating-current system for electric operation, or to discuss the relative merits of the ground rail and of the overhead wire for transmitting the current At the present time the direct-current system is more widely adopted than the alternating-current form

Auxiliary and subsidiary businesses owned by railways have become important parts of their activities The owners of the earliest railways were in theory toll-takers only, that is, they took toll of any traffic passing over their 'rail ways' but they did not operate the traffic The business of railway haulage and the provision of terminal stations soon followed To these services other specialized services have been added, such as the provision of storage accommodation for luggage and goods, the provision of sleeping-berths on trains, the hire of pillows and rugs to passengers, and numerous other services which were not contemplated originally as among the functions of a railway

Another group of services provided for the comfort of railway travellers may be seen in the bookstalls, tobacco, fruit, and sweetmeats kiosks, and the refreshment rooms at stations, to which should be added the restaurant cars on trains. In this country catering services are performed either by the railway company or by contractors, but the general practice nowadays is for the railway company to work its own catering services in conjunction with its hotels. It should be noted, however, that the Pullman cars and the Southern Railway Company's refreshment cars are exceptions to this practice. They are conducted by separate companies.

The railway-owned and the railway-managed hotels are obviously a distinct departure from the function of transportation. Their job is to foster and facilitate passenger traffic. Apart from this purpose they are themselves a remunerative sideline of the railway business. Apparently, the first railway hotel was that at Euston, which was designed in 1838 as two separate buildings: a hotel and dormitories for the accommodation of the passengers on the then London and Birmingham Railway. It is interesting to note that among the attractions held out in the prospectus were the provision of baths 'in convenient situations', and the assurance that a licence for the sale of wines and spirits was not contemplated! It is a long way from this original hotel to the sumptuous Gleneagles Hotel of the L.M.S.R. or to the modern hotels of other railway companies.

Of other railway-owned businesses the largest is probably that of docks. We must, however, be content merely to mention them, together with the shipping services and the road cartage services, which are essentially feeders of railway services.

The writer cannot bring this book to a close without confessing his consciousness of how very much has been left out. Nevertheless, he hopes that he may have said enough to show clearly how the various activities

involved in running a railway are interdependent, and that it is only by the constant and careful co-ordination of these many diverse operations that any railway can be made to 'go' The passenger who is being transported in comfort over the iron road in some crack express may reflect that hundreds of railway folk have planned long ahead and co-operated in all sorts of ways, down to the moment when he got aboard and even while he is travelling, to ensure as far as possible that he arrives at his journey's end safely and in time, and that this mighty and intricate machine which we call 'a railway' has evolved from two simple ideas the reduction of friction by providing 'rail ways' for wheeled vehicles, and the use of the expansive force of steam to move the vehicles

PRINTED IN GREAT BRITAIN AT THE UNIVERSITY PRESS, OXFORD
BY JOHN JOHNSON, PRINTER TO THE UNIVERSITY